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A Magazine of Methods for Operating Men

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The Course of Oil

By K. C. SCLATER

Authoritative Data to Be Published

The development of so-called distillate fields, most of which are of recent discovery, has accentuated the need for fundamental data regarding natural gas and other hydrocarbons and their behavior at extremely high pressure. In these fields the pressures encountered are great enough that natural gas departs appreciably from ideal gas laws. This poses a problem.

Other problems arise concerning solubility and shrinkage. These are important in the estimation of natural gas and crude oil reserves.

In an effort to supply some of these fundamental data and foster their application in practice, *The Petroleum Engineer* will publish a series of articles by Dr. George Granger Brown, an authority on this subject. The first article of the series appears in this issue.

It is hoped before the series is over to provide helpful data on such subjects as the equilibrium between liquid and vapor phases of natural gasoline hydrocarbons, the computation of liquid-vapor separation, the design of fractionating columns for rectifying natural gasoline, the direct fractionation of natural gas, and high-pressure polymerization.

Refining Technology Series

So great is the progress in refining practice these days that it is difficult to keep up with the many new advances. A series of articles on refining technology will therefore be presented throughout 1940. This series will be prepared by Arch L. Foster, an authoritative writer on petroleum refining subjects. The first article in the series appears in this issue.

The series of articles will deal with the latest developments in modern petroleum refining technology, thus affording readers a valuable purview of this field.

Aids in Development Problems

For those who would produce their wells wisely and efficiently, a knowledge of the properties of the reservoir fluids being produced is helpful, if not essential. Contrary to prevailing opinion, the determination of these properties is not so difficult that it cannot be made by the average operator.

Those who seek enlightenment on what properties of reservoir fluids are important in production practice, how they are determined, and how the information may best be applied to production problems, are referred to a recent government publication (U. S. Bureau of Mines, Report of Investigations 3474, on "*Properties of a Petroleum-Reservoir Liquid and Its Residua with Application of the Data to Production Problems*"), which may be obtained at nominal cost from the Superintendent of Documents, Washington, D. C.

It describes the equipment and the method of procedure used in procuring and testing samples of reservoir fluids, and illustrates by examples the practical application of the data after they are obtained.

In discussing the possible effect of changing fluid properties on pressure gradient in the formation, the authors point out that "it is important that the engineer consider possible changes in the reservoir-fluid properties before attempting to plan the well spacing that will accomplish the desired results. Although the average reservoir presents a complexity of factors that make the problem of well spacing and optimum production rates difficult, there is ample justification for obtaining information on the specific volume, viscosity, and other properties of reservoir fluids and determination of the relation between these properties and the effective permeability of the producing formation."

An important observation is made also with regard to energy and decline of reservoir pressure: "Production engineers are concerned with the decrease in energy that occurs as reservoir pressures decline because the methods and rates of recovery depend on this factor. The energy available by expansion of reservoir fluids having compositions corresponding to three stages of depletion were estimated from experimental data obtained from residua of the original fluid."

The value of this report lies in the fact that it deals with the practical application of technical data to some fundamental problems of oilfield development that concern nearly all operators.

Electric Logs in Drilling

Of all scientific inventions that have come to the aid of oilfield development, none surpasses electrical logging in importance and practical value. Ten years ago it was introduced into the oilfields of the United States. Today it is an essential in modern drilling operations.

Electric logs established their usefulness overnight because the value of the data they yielded was immediately recognized; further, the data were in tangible form. They give a picture of the formations penetrated, their character and characteristics. Electric logs can reveal with an uncanny degree of accuracy the presence and location of oil-bearing formations exposed in the hole. They are perhaps the greatest aid to deep drilling operations at present in use.

Despite this fact, means to improve electrical logging methods are being sought, and innovations in this art are of immediate interest to the entire industry.

One such innovation, the subject of an article in this issue, is a new system designed to provide a continuous electric log of the well while drilling. Information regarding the formations being penetrated by the bit are instantly available on a chart at the wellhead. Therein it differs from conventional electrical logging methods in use.

The conductor used is, in effect, an integral part of the drill stem. Six wells have been drilled to test the practicability of the system and its mechanical equipment.

Should the system prove as successful as it gives promise of being, it will enhance the value of the electric log—an already priceless tool.

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« « HIGHLIGHTS IN OILDOM » »

East Texas Bottom-Hole Pressure Shows Decline of 5.9 Lb.

Dr. F. V. L. Patten, director of production for the Texas Railroad Commission, states that the January 8 bottom-hole pressure tests for the East Texas field showed a decline since December 8 of 5.9 lb., lowering the average per sq. in. to 1060.5 lb. During the period from November 8 to December 8 the pressure decline was 4.4 lb.

The latest readings brought the commission's figures for the two-month period in line with those of the East Texas Engineering Association, which tests approximately 1300 wells compared to 91 by the commission. Dr. Patten said that the association, which makes its tests on different days than the commission, had recorded a decline of 8 lb. in November and 2 lb. in December, a total of 10 lb. The commission's figures of 4.4 lb. for November was at variance with the association's figure, but the total of the two bodies for the two-month period was virtually the same.

The decline during December, both with respect to the total allowable and on a basis of per 1,000,000-bbl. allowable, was greater than in November, according to the commission's tests. For the period ended December 8 the decline was slightly more than one-third lb. per 1,000,000 bbl. allowable, whereas in the period ended January 8 the decline was slightly less than one-half bbl. per 1,000,000 bbl. allowable.

●

Illinois Regulation Bill is Prepared

Governor Henry Horner's proposed bill regulating Illinois' oil industry, which is to be presented to the forthcoming special session of the legislature, has been submitted to the attorney general for a technical checkup, it has been learned.

Detailed contents of the measure were not revealed, but it is believed it will deal principally with proration and a tax on the state industry. Many think it to be a revised version of the earlier proposed measure drafted by the legislative committee that toured the Illinois oil fields to study conditions.

●

Eastern Crude Oil Prices Again Advanced

Crude oil prices in the Pennsylvania Grade district of Pennsylvania, West Virginia, southeast Ohio, and northwestern New York have again been advanced, the seventh increase for the area since January 20, 1939. The advance of 25 cents a bbl. was announced by the Joseph Seep Purchasing Agency for the South Penn Oil Company. The new South Penn schedule follows: New York Transit Lines, $2.75 a bbl.; Southwest Pennsylvania Lines, $2.40 a bbl.; Eureka Pipe Lines, $2.34 a bbl., and Corning (unchanged), $1.12 a bbl.

Tide Water-Associated Oil Company and the Ohio Oil Company followed South Penn's lead and announced a $2.75 a bbl. price for crude oil in the Bradford-Allegheny district.

●

Plan for Developing and Producing Kettleman Eocene Zone

A plan for developing and producing the Eocene zone at Kettleman Hills, California, has been submitted by the Kettleman North Dome Association to all operators at Kettleman Hills who are not members of the association and whose properties are probably underlain by the Eocene.

The plan is based on gas production from the Eocene formation, it having been the Kettleman North Dome Association's contention for a number of years past that Kettleman oil production must be considered in relation to the gas production from the field. The plan establishes quarter-sections as Eocene operating units, Eocene production from each quarter-section to be governed by characteristics of the Eocene formation underlying any given section in comparison with that underlying the "master" quarter-section. Superior Oil Company's quarter-section, the Huffman lease, has been selected as the "master Eocene operating unit", hence, if the plan is generally adopted by operators in the area, all other quarter-sections in the field will be produced in relation to that quarter-section. Eocene gas production from the Huffman quarter-section will be approximately 5,000,000 cu. ft. per day with oil production at about 200 bbl. per day and Eocene production from other quarter-sections will approximate that figure.

The plan has been submitted to all operators in the field who are not members of the association. These operators are: Standard Oil Company, Union Oil Company, Superior Oil Company, and Robert S. Lytle. None has offered any criticism of the fundamentals of the plan, and the association has reason to hope that it will be adopted. In an effort to speed its adoption, the association has for the first time cut its daily oil production below the minimum set up in the Kettleman unit plan agreement. This action, which reduces Kenda's oil output by 2553 bbl. per day, required the unanimous vote of the association's board of 11 directors. If other operators follow Kenda's action, total reduction of oil output from the field will be approximately 7500 bbl. per day, bringing daily production down to 44,854 bbl., from current levels approximating 52,500 bbl. per day.

The association's action is for the month of January only. If reductions in Kettleman gas production are made, and if the Eocene plan is adopted, it is possible that the January production cut will be continued.

The association contends that to continue to take gas from the field at the present rate, yet to reduce oil production to any disproportionate extent and thereby increase gas-oil ratios, is actually to create a condition of "waste." The Eocene plan, in which gas production and oil production are definitely linked through engineering formulas, will avoid such a condition with respect to production from the comparatively recently discovered deep Eocene formation.

●

Seminole, Texas, Operators Agree On Rules

Operators in the Seminole pool, Gaines County, Texas, have agreed on field rules and have submitted them to the Texas Railroad Commission for consideration.

The rules agreed upon are:

Forty-acre units, having 10-acre tolerance, the wells being drilled 1320 ft. apart and 660 ft. from lease lines, exceptions to the spacing rule to be granted only after the applicant shows a bona fide effort to pool.

Three strings of casing are required; surface casing set 50 ft. below the redbeds and cemented to the surface; intermediate string set at or below the Yates sand and cemented 1500 ft. above the shoe; and the producing string set below the gas-oil contact and cemented 1000 ft. above the guide shoe.

Proration is suggested on a basis of 75 percent to acreage and 25 percent to potential, potentials to be taken on a six-hour test through 2½-in. tubing, the daily potential being computed by taking the smallest three-hour flow of the six hours and multiplying by eight. Gas-oil ratio of 2500 to 1, with displacement factor, and with a volumetric withdrawal rule for gas wells in the field, are included in the proposals.

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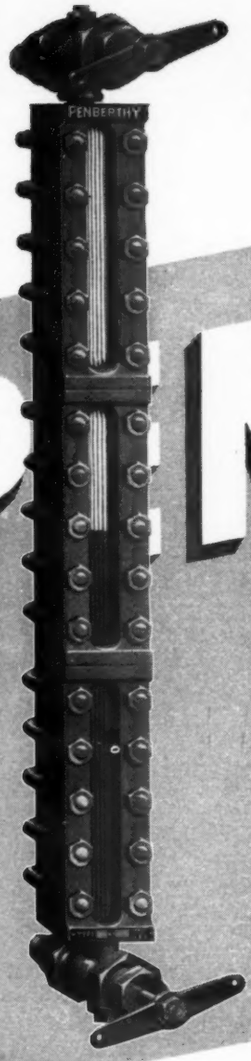

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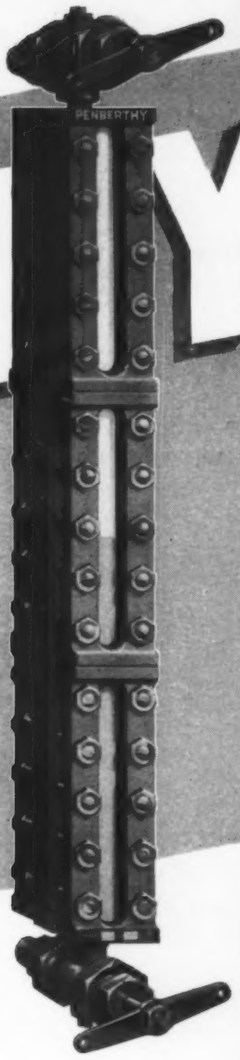
LIQUID LEVEL GAGES



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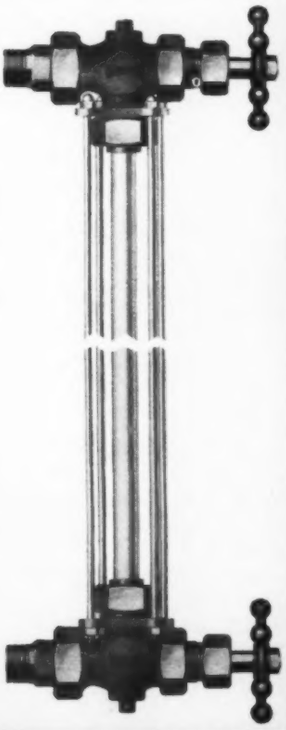

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PENBERTHY PRODUCTS

Activities in Refining

Percent Refining Capacity Operated

Western Division, 55.2 Percent **Central Division, 74.7 Percent** **Eastern Division, 91.5 Percent**

THE A. G. DEGVIELA, Riga, Latvia, operating on State capital, is constructing a petroleum refinery built according to American patents. The plant is to be ready for operation in the spring. A. G. Degviela also is storing used motor oil, to be reconditioned. For such oil, suitable for reconditioning, a price of 23 sant. per kilogram (17 cents per gal.) is being paid.

•

Construction of a recycling plant 19 miles northeast of McAllen, San Salvador field, Hidalgo County, Texas, is planned by the Gulf States Oil Company. The company owns distillate production in the area and has let a contract to the Rudel Drilling Company to drill another well to a depth of 9000 ft.

•

Sinclair Refining Company has under construction an absorption-type gasoline plant in the East Whitepoint field, Texas, which is expected to be completed the latter part of January. Its capacity will be 8,000,000 cu. ft. of gas per day. Dresser Engineering Company, Tulsa, Oklahoma, is the contractor.

•

According to a recent announcement, refiners of South Texas and South Louisiana plan to spend approximately $20,000,000 duing 1940 expanding their plants. Included are the Humble Oil and Refining Company, Shell Oil Company, Inc., Sinclair Refining Company, Magnolia Petroleum Company, Pan American Refining Company, Gulf Refining Company, The Texas Company, Republic Oil Refining Company, Barnsdall Refining Company, and Standard Oil Company of Louisiana.

•

Walter Trout and Associates have acquired an 8-acre site 10 miles south of Yazoo City, Yazoo County, Mississippi, and plan to move to it a 1600-bbl. refinery unit from the East Texas field. Location is near Tinsley Dome and on the Yazoo and Mississippi Valley railroad.

Crude Runs to Stills, Gasoline, Gas and Fuel Oil Stocks
Week Ended December 30, 1939
A. P. I Figures
(Figures in thousands of bbl. of 42 gal. each)

DISTRICT	Percent Potential Capacity Reporting	Daily Average Crude Runs to Stills	Percent Operated of Total Capacity Reporting	Total Motor Fuel Stocks	Total Gas and Fuel Oil Stocks
East Coast	100.0	586	95.3	18,910	19,217
Appalachian	87.3	132	91.0	3,544	927
Ind., Ill., Ky.	90.7	516	88.2	11,939	7,232
Okla., Kans., Mo.	81.6	258	75.4	6,918	3,993
Inland Texas	50.3	117	73.6	1,754	2,198
Texas Gulf	90.0	798	84.0	11,961	10,827
La. Gulf	97.8	109	62.3	2,399	2,240
N. La. and Ark.	55.0	43	78.2	500	772
Rocky Mt.	54.2	29	45.3	1,123	563
California	90.0	486	65.2	16,277	89,965
Reported	86.4	3,074	80.2	75,325	137,934
Estimated Unreported	.....	371	.....	5,660	2,930
*EST'D TOTAL U. S. DEC. 30, '39	.....	3,445	.....	80,985	140,864
*EST'D TOTAL U. S. DEC. 23, '39	.....	3,395	.....	78,707	142,129
U. S. B. of M. *EST'D TOTAL *DEC. 30, '38	.....	3,160	.....	71,542	142,623

*Estimated U. S. Bureau of Mines' basis.
**December, 1938, daily average.

The capacity of the Ardmore, Oklahoma, refinery of the Ben Franklin Refining Company will be increased from 3500 bbl. per day to 6000 bbl. per day, it has been announced.

•

The capacity of Phillips Petroleum Company's Kansas City, Kansas, refinery is to be increased 5000 bbl. per day, according to an announcement by Frank Phillips, chairman of the board of the company. The plant is the largest refinery in Kansas, having a capacity of 23,000 bbl. per day. Its crude oil supply is obtained from Kansas fields through the company's pipe-line system that connects with virtually every producing area in the state.

•

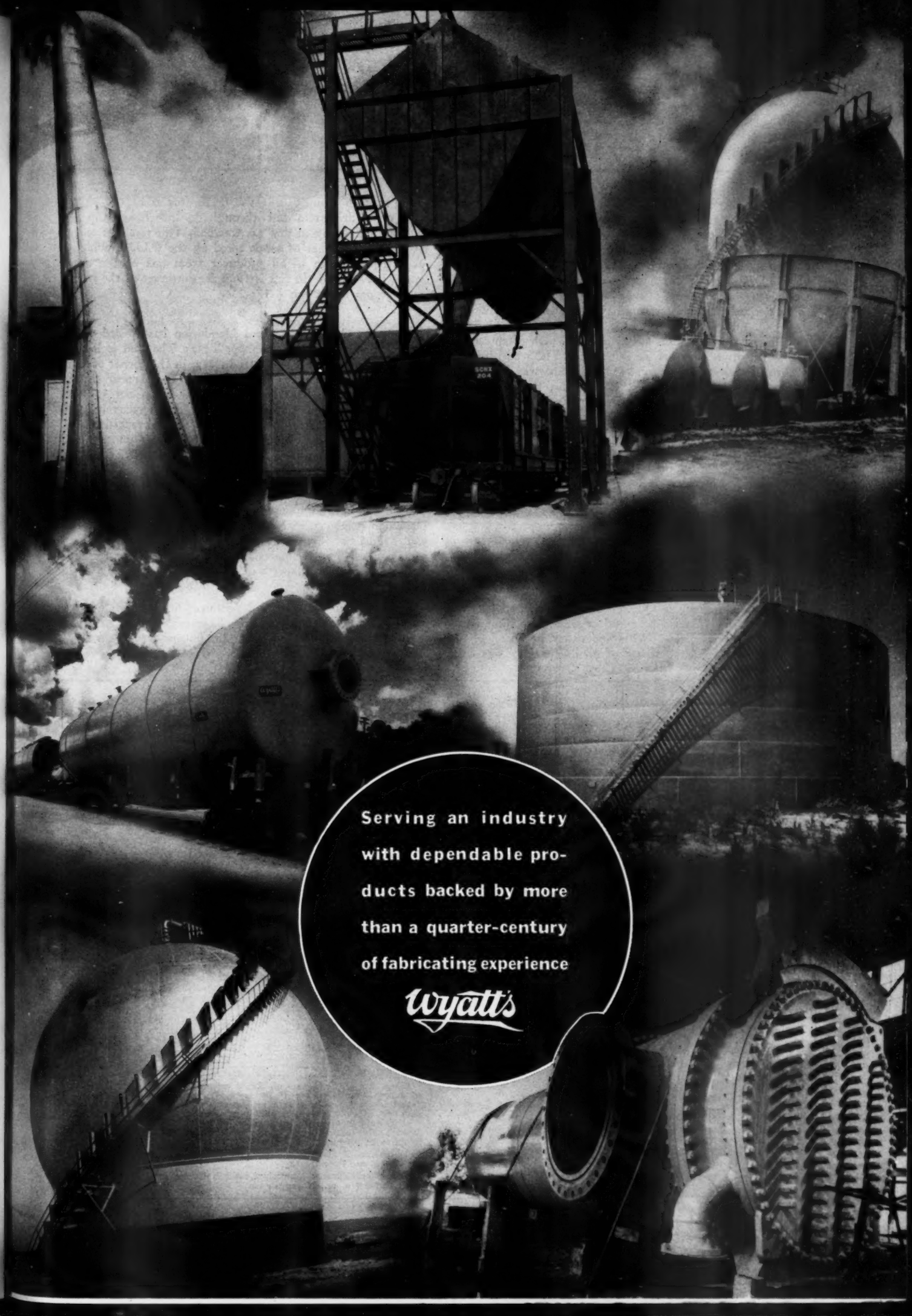
The natural gasoline plant being erected by the Arkansas Fuel Oil Company in the Waskom gas field, Harrison County, Texas, is expected to be completed the early part of February. The plant will have a capacity of 20,000,000 cu. ft. of gas per day and will be connected to five gas wells producing from the Travis Peak and Pette zones. Recovery is expected to average 300 gal. of gasoline per 1,000,000 cu. ft. of gas. Location of the plant is in the Abney headright survey.

•

Johnson Oil Refining Company, Cleveland, Oklahoma, is constructing a natural gasoline plant of the compression type near Keystone, Pawnee County. The plant is in section 27-20-9 in an area where the company has a number of producing wells from which gas will be obtained. The capacity will be 750,000 cu. ft. of gas per day. It is expected that the plant will be in operation by February 15.

•

A natural gasoline plant having a capacity of 20,000,000 cu. ft. of gas per day will be erected near Coalinga, California, by the Standard Oil Company of California. Gas supply will be from the Coalinga-Amerada area and a booster station and pipe line are to be constructed.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Activities in the Oil Fields

MARTIN-WESTBY-GREEN, Inc., have opened a new Wilcox sand pool in section NW of 24-14-10e, southeastern Creek County, Oklahoma, with their No. 1-A Judeman. The new pool is east of the old Hall-Donnelly pool and about 45 miles from Tulsa. Production is from a depth of 3180-97 ft. The discovery is rated as a 75-bbl. per day well.

Jock Garden and associates have successfully brought-in their No. 1 Rahn, a wildcat in C SW SW NW of 13-34-5e, 10 miles east of Arkansas City, Kansas, which produced 150 bbl. of oil in an hour on the initial test. The well originally was drilled to a depth of 3436 ft., but was shut-down temporarily for the operators to clear-up titles, and then was plugged-back to 2945 ft. Production is from the Burbank sand. The oil tested 39.8 gravity.

●

No. 1 Petty Stave of Standard Oil Company of Louisiana, a wildcat in C SE SE of 4-17s-21w, Arkansas, flowed 160-bbl. of distillate in 24 hours through 7/32-in. choke and produced 4,100,000 cu. ft. of gas. The well is on the Big Creek structure, northwest of Magnolia in Columbia County. The well was drilled to a total depth of 7999 ft., but encountered salt water and was plugged-back to 7988 ft. and the casing gun-perforated with 100 shots from 7980 ft. to 7988 ft.

●

Tide Water-Associated Oil Company's No. 1 Delta Farms, Lafourche Parish, Louisiana, gives promise of opening a new coastal field. The wildcat, drilled to a total depth of 11,850 ft., had several good showings of oil in sand sections from 8900 ft. to bottom. Casing was perforated at 11,780-800 ft. and on a drill-stem test through ¼-in. chokes top and bottom a showing of dry gas was had. This test was on the lowest of a number of sands cored by the wildcat, which is expected to make an oil producer from one of the upper sands. Location of the test is 1980 ft. southeast of the northwest corner of section 6-17s-23e.

●

Shell Oil Company's No. 1 Henderson has opened a new producing area in Clay County, Texas. The well is located on block 2605 of the T E & L Survey, in the corner of Clay County and three miles from the Jack and Archer county lines. Three sands have been found, the last from 3570-85 ft., and a drill-stem test made at that depth recovered 240 ft. of oil, 300 ft. of oil mud, and 120 ft. of brackish water. The operator cored ahead from 3585 ft. to 3600 ft. and recovered 15 ft. of hard sand showing oil.

●

Arthur "Tex" Harvey, discoverer of the Tonti pool, Marion County, Illinois, has now brought-in the pool's first Devonian producer with his No. 6 Kagy, SE 33-3n-2e. The test, drilled to a depth slightly below 3500 ft., started flowing by heads, and estimates rated the well as good for possibly 1000 bbl. of oil per day.

●

Barnsdall Oil Company and Wilshire Oil Company's No. 1 Santa Fe, a semi-wildcat in the Rosecrans area, California, produced 1100 bbl. of oil and 1,500,000 cu. ft. of gas from a total depth of 8792 ft. on the initial test.

AVERAGE CRUDE OIL PRICES

California	
Kettleman Hills	$1.19-1.43
Playa Del Rey	.80-1.16
Coalinga	.70- .90
Wilmington	.75-1.21
Montana	.90-1.10
Wyoming	.35-1.30
Colorado	.90- .98
New Mexico	.53- .95
Texas	
North Central	.71-1.03
Panhandle	.67- .96
West Texas	.53- .95
Gulf Coast	.86-1.28
Darst Creek	.96
East Texas	1.10
Talco	.65
Kansas	.60-1.10
Oklahoma	.60-1.10
Arkansas	.73-1.05
Louisiana	
Rodessa	$1.05
Gulf Coast	.79-1.28
North Louisiana	.73-1.05
Illinois	.95-1.05
Kentucky	.90-1.10
Indiana	.95
Ohio	
Lima	.90
Michigan	.74-.97½
Pennsylvania	
Bradford	2.75
Southwest	2.40
Eureka	2.34
Buckeye	2.30
Corning	1.12
Canada	2.10-2.17

DAILY AVERAGE CRUDE OIL PRODUCTION

Data Supplied by A. P. I.

(Figures in bbl. of 42-gal. each)

	[1]B. of M. Calculated Requirements (December)	Week Ended Dec. 30, 1939	Week Ended Dec. 2, 1939	Week Ended Dec. 31, 1938
Oklahoma	437,600	[2]418,200	[2]408,950	421,900
Kansas	168,000	[2]178,600	[3]177,250	149,100
Nebraska	.....	.....	[3] 50	.....
Panhandle Texas	.....	73,600	61,150	62,300
North Texas	.....	76,350	74,100	77,850
West Central Texas	.....	26,850	24,700	30,000
West Texas	.....	227,150	184,950	202,500
East Central Texas	.....	81,600	79,350	95,000
East Texas	.....	394,400	299,000	371,850
Southwest Texas	.....	202,550	154,150	229,300
Coastal Texas	.....	223,400	183,050	211,500
TOTAL TEXAS	1,438,100	1,305,900	1,060,450	1,280,300
North Louisiana	.....	68,200	69,650	66,750
Coastal Louisiana	.....	198,850	202,550	187,500
TOTAL LA.	255,200	267,050	272,200	254,250
Arkansas	56,100	70,650	70,250	49,700
Mississippi	.....	[3] 1,700	[3] 1,250	.....
Illinois	315,200	337,850	330,950	137,000
Eastern (Not incl. Illinois)	104,600	103,600	105,750	89,550
Michigan	61,000	67,300	65,150	46,200
Wyoming	60,000	62,750	70,250	46,600
Montana	15,200	17,050	17,050	12,350
Colorado	4,200	4,200	4,000	3,950
New Mexico	110,000	109,050	110,750	98,550
TOTAL EAST OF CALIF.	3,025,200	2,943,900	2,694,300	2,589,450
California	594,500	601,100	594,900	614,900
TOTAL U. S.	3,619,700	3,545,000	3,289,200	3,204,350

[1]These are U. S. Bureau of Mines' calculations of the requirements of domestic crude oil based upon certain premises outlined in its detailed forecast for the month of December. As requirements may be supplied either from stocks, or from new production, contemplated withdrawals from crude oil inventories must be deducted from the Bureau's estimated requirements to determine the amount of new crude to be produced.

[2]Oklahoma, Kansas, Mississippi, and Nebraska figures are for week ended 7 a. m., December 27.

[3]Oklahoma, Kansas, Mississippi, and Nebraska figures are for the week ended 7 a. m., November 29.

Great Pioneers

NEW MEXICO 1827

Wagon-trains on the Santa Fe Trail—high adventure—America in the making—with twenty states yet to be carved from this vast unknown area west of the Mississippi. The territory of New Mexico, as it actually stood in 1867, was admitted as the forty-seventh state of the Union in 1912.

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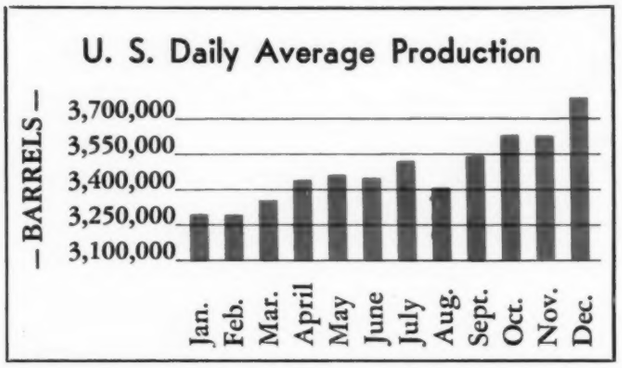
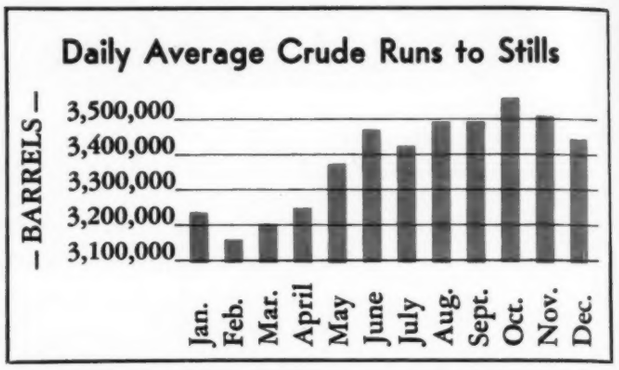
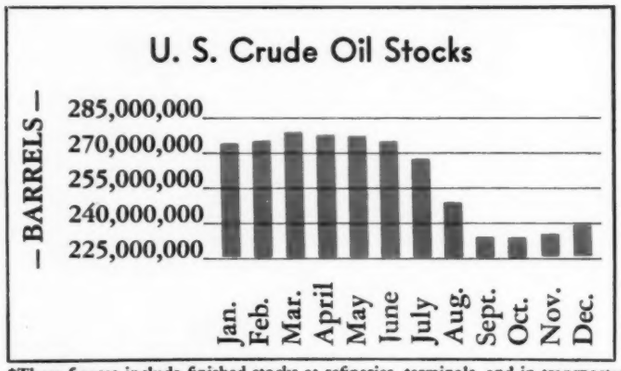
DOWELL INCORPORATED KENNEDY BLDG., TULSA, OKLAHOMA

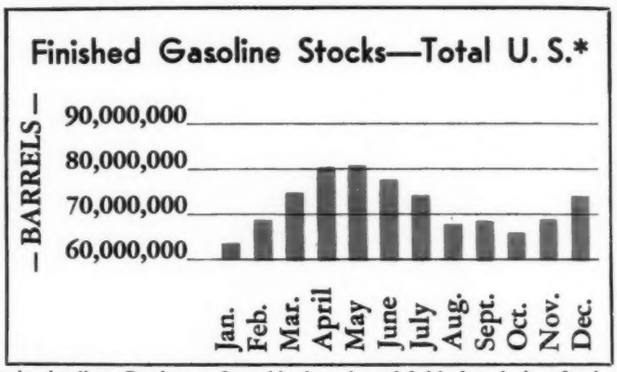
Subsidiary of The Dow Chemical Company

Petroleum Statistics and Field Activities









*These figures include finished stocks at refineries, terminals, and in transportation in pipe lines. Previous to June this chart showed finished stocks in refineries only. Above statistics by the American Petroleum Institute.

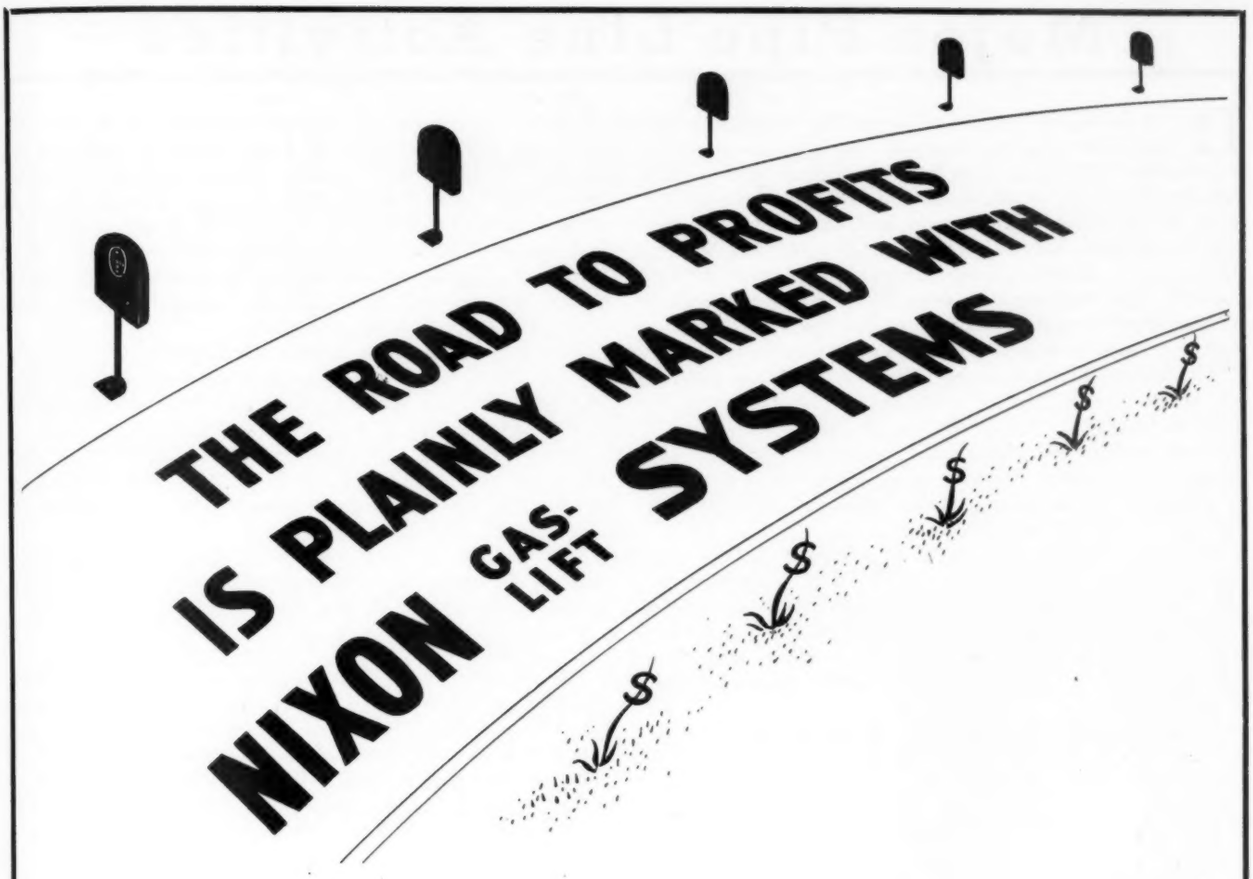
Summarized Operations in Active Fields for December, 1939

Fields	Completions	Producers	Rigs	Drilling Wells	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
TEXAS								
East Texas	19	19	6	17	3500-3700	2	40	Rotary
Duval County	43	26	4	15	1554-2900	2	22	Rotary
Ector County	50	50	10	76	3675-4377	2 and 3	32-36	Rot.-Cab.
Panhandle	61	56	18	64	1700-3900	2	40	Rotary
Refugio County	8	7	2	5	4900-5900	2	38	Rotary
Nueces County	20	18	5	14	3922-5878	2 or 3	21-54	Rotary
Winkler County	8	8	2	5	2850-3450	2 and 3	30-38	Rot.-Cab.
K. M. A. Field	37	34	22	47	3730-3935	2	42-43	Rot.-Cab.
OKLAHOMA								
Oklahoma City	3	3	1	2	6450-6682	3	39	Rotary
Fitts Pool	8	6	2	8	1800-4488	2 or 3	38	Rotary
KANSAS								
Russell County	41	37	10	30	2926-3435	2 and 5	32-37	Rot.-Cab.
Rice County	22	18	8	29	3222-4085	2 and 5	42-48	Rot.-Cab.
Barton County	25	20	2	23	3290-3518	2	39-42	Rot.-Cab.
ILLINOIS								
Central Illinois	405	336	306	101	1425-4100	2	36-38	Rot.-Cab.
NEW MEXICO								
Lea County	37	34	12	61	3150-4030	3	30-34	Rot.-Cab.
CALIFORNIA								
Kettleman Hills	4	4	6	18	8300-8730	3 or 4	40	Rotary
Wilmington	15	15	16	15	3500-4000	2 and 3	18-20	Rotary

Field Activities by States for December, 1939

State	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1938 (In Barrels)
	December	November	December	November	December	November	December	November	December	November	
Arkansas	17	15	12	13	15	26	5	24	45	33	18,211,617
California	111	117	101	107	81	209	85	98	206	215	249,918,001
Colorado	0	1	0	0	....	....	1	2	32	34	1,371,687
Illinois	405	366	336	286	479	488	306	300†	101	97	23,306,000
Indiana	50	51	32	40	....	....	8	10	70	69	965,900
Kansas	147	149	117	114	194	256	48	52	273	275	58,795,545
Kentucky	68	64	33	38	....	....	10	12	101	106	5,828,650
Louisiana	156	135	114	97	151	188	35	....	185	....	94,941,537
Michigan	140	124	87	76	121	153	39	46	173	172	19,140,966
Mississippi	9	4	4	2	....	....	5	7	22	14	Gas. Prod.
Montana	16	16	14	11	....	....	3	3	43	41	4,858,458
New Mexico	65	62	53	56	64	65	24	21	142	140	39,902,263
New York	102*	96*	102*	96*	....	....	13	7	46	43	5,040,600
Ohio	104	110	76	74	....	....	38	44	185	192	3,292,100
Oklahoma	216	190	124	123	216	221	45	40	315	312	171,312,098
Pennsylvania	162*	142*	160*	140*	....	....	....	....	....	....	17,431,500
Tennessee	0	0	0	0	....	....	....	....	....	....	....
Texas	901	847	687	640	1122	1044	420	375	1382	1202	473,304,662
West Virginia	75	68	63	56	....	....	23	21	150	149	3,700,375
Wyoming	14	14	10	11	....	....	4	5	65	69	19,005,638
Total	2758	2572	2125	1980	2443	2650	1112	1067	3536	3163	1,206,827,597

*Inludes water-intake and pressure wells.
†Includes 257 rigs standing and 43 rigging-up.



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Savings begin with its purchase and installation, which are considerably lower than standard pumping rigs. Operating costs are less, because only a minimum volume of inexpensive gas pressure is required to bring fluid to the surface. Since so few parts are subject to wear, maintenance costs are practically eliminated.

Wells of any depth, flowing from any level, producing any volume can be successfully and economically put on the Nixon Surface Control Gas-Lift System.

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EXCLUSIVE GULF COAST DISTRIBUTORS FOR: Wilson-Snyder Pumps; American Cable Tru-Lay Pre-formed Wire Rope; Kewanee Boilers; Sievers Reamers; Drift Meter, Jr.; Gray Swivel; Nixon Surface Control Gas Lift; Nixon True-Taper Slip and Spider; Bowen Pack-Off and Releasing Drill Pipe Overshot; Douglas Weight Indicator.

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Major Pipe Line Activities

DETAILS of the Panhandle Eastern Pipe Line Company's expansion program involving the expenditure of approximately $3,500,000 have been announced. The program consists principally of the installation of approximately 137 miles of 24-in. and 22-in. main line loops. The program, when completed, will add between 25,000,000 and 30,000,000 cu. ft. of natural gas per day to the company's delivery capacity, thus enabling it to meet the increasing demands of its customers already connected to its pipe-line system, as well as to serve additional customers in its trade territory.

The lines to be constructed will be in the states of Kansas, Missouri, and Illinois. In addition to the loop construction, the program includes the installation of an additional 1000-hp. compressor unit at the company's Glenarm compressor station about 18 miles south of Springfield, Illinois, as well as certain additions to its existing gasoline extraction and dehydration plant near Liberal, Kansas.

Contracts for the pipe required to carry out this construction have been awarded to the A. O. Smith Corporation of Milwaukee, Wisconsin, and the National Tube Company of Pittsburgh, Pennsylvania. Approximately 25,000 tons of steel will be required. Loop construction contracts have been awarded to T. R. Jones and I. C. Little, both of Dallas, Texas.

Construction of the pipe lines has begun, and it is expected that the work will be completed by late winter or early spring.

●

Allen Junkin, counsel for the Kansas Pipe Line and Gas Company, Chicago, Illinois, early this month discussed with officials of the Reconstruction Finance Corporation at Washington, D. C., a request for a $18,400,000 loan by his company to finance a 1000-mile extension to its natural gas pipe-line system into the Mesabi iron range of Minnesota. Junkin was accompanied by D. H. Holmes, vice-president and treasurer of the Kansas Pipe Line and Gas Company, and they spent considerable time in conference with Frank Ronan, chief of the RFC industrial lending section, going over details of the plans. Results of the meeting have not been announced.

The pipe line company now operates 625 miles of pipe lines in Nebraska and Kansas. The plan under consideration would extend these lines from the Hugoton field, southwestern Kansas, and from fields in Oklahoma and northern Texas to the Mesabi range. The company proposes to supply natural gas to various cities for domestic, commercial, and industrial use, as well as for the processing of iron ore in the Mesabi range.

More than a year ago an application was filed with the Federal Power Commission for approval of the plan. The commission gave its approval subject to certification by the pipe line company that it would be financially able to carry through the project.

●

The Stanolind Pipe Line Company has announced that construction will begin as soon as weather permits on a 140-mile pipe line from the Bemis pool, Ellis County, Kansas, to the company's station at Washington, Kansas.

The line will be of 8-in. and 10-in. pipe and will connect with the company's trunk line from Wyoming. The latter line ties-in at Carrollton, Missouri, to the main Mid-Continent line to Whiting, Indiana.

Officials of the Sinclair Refining Company, Pipe Line Department, have announced that the company will loop its pipe line from the K.M.A. field, Wichita County, Texas, to its Hensley pump station, Jack County. The project will involve the laying of 66 miles of 8-in. line, construction work to begin by February 1 and scheduled for completion about March 15. The K.M.A. station will be enlarged and a small gathering station will be installed in the northern end of the Hull and Silk pool, Archer County.

The loop will be to a 6-in. line completed by the company in May, 1939, which has a capacity of 10,000 bbl. per day. The new line will increase the capacity of the system to 23,000 bbl. per day.

Sinclair Refining Company, in the K.M.A. field, is connected to 112 leases upon which are 461 producing wells. In the Hull and Silk pools the company is connected to 24 leases and 63 producing wells.

Last May the company relieved The Texas Pipe Line Company of a number of connections that the latter had been forced to prorate due to lack of line capacity.

●

Magnolia Petroleum Company has completed its 139-mile gasoline pipe line from San Antonio to Corpus Christi, Texas. The line was laid of 4-in. and 6-in. pipe, 119 miles of the former and 20 miles of the latter. The capacity of the line is 4500 bbl. per day. A smaller line from the Luling refinery of the company to San Antonio is replaced between those two points by the new line.

●

Williams Brothers Corporation, Tulsa, Oklahoma, has been awarded a contract by The Texas-Empire Pipe Line Company to lay 80 miles of loops to its system in Illinois. Between the Heyworth and Salem stations 42 miles of 10-in. will be laid, and between Wilmington and Heyworth stations, 38 miles of 12-in. One pumping unit will be added at each of the four stations, at Salem, Brownstown, Assumption, and Warrensburg.

●

New Mexico Gas Company, an affiliate of the Southern Union Gas Company, Dallas, Texas, is laying a 31-mile, 6-in. natural gas line from Albuquerque to Belen, New Mexico.

●

Under the terms of a franchise taken over from Wain Town and Gas Company, Franco Oils, Ltd., will lay a transmission line and distribution system for Vermilion, Altamont, Canada. Work will begin in the spring. The project will involve the expenditure of about $100,000.

●

Southern Natural Gas Company, Birmingham, Alabama, recently completed the construction of a 32-mile, 18-in. natural gas loop from its compressor station at Onward, Mississippi, to a point south of Yazoo City, Mississippi. Maximum working pressure of the line is 425 lb. per sq. in. The contractor was the B. and M. Construction Company, Oklahoma City, Oklahoma.

●

Amsco Pipe Line Company has completed the laying of a 16-mile, 4-in. pipe line from the S. R. C. field in Duval County, Texas, to the Adami field, northwest Webb County. Oil is run to storage in the former field, then picked-up by the Magnolia Pipe Line Company and transported to Corpus Christi.

THE Petroleum Engineer

JANUARY, 1940

A PETROLEUM ENGINEER FEATURE

The Compressibility of Gases

I. Pure Gases

By
GEORGE GRANGER BROWN

Professor of Chemical Engineering, University of Michigan

IN dealing with gases at low pressure, the ideal gas relationship has been, and is, a convenient and generally satisfactory tool, which in the past has also been used for computations under pressure. But when faced with measurements and calculations for gases under high pressure the use of the ideal gas relationship may lead to errors as great as 500 percent, as compared with 2 or 3 percent at atmospheric pressure.

Most of us have heard of various equations of state used for representing the pressure-volume-temperature relationships of gases, but these are generally complicated and inconvenient in practical use. In this discussion the use of the compressibility factor, which is reasonably convenient and sufficiently accurate for present engineering requirements, will be described.

The Ideal Gas Relationship

The ideal gas relationship is well known and is usually written:

$$PV = NRT \quad \ldots\ldots\ldots\ldots \quad (1)$$

where

P = pressure, absolute in lb./sq. in.

V = volume in cu. ft.

N = No. of lb. moles, or $\frac{\text{lb.}}{\text{molecular wt.}}$

R = 10.71 for all gases

T = temperature, absolute, (460 + °F.)

Van der Waal's Equation

Van der Waal's equation was derived from considerations of the kinetic theory of gases as corrected for volume of molecules and the attractive forces between molecules and is written:

$$\left(P + \frac{N^2 a}{V^2}\right)(V - Nb) = NRT \, . \quad (2)$$

where, *a*, and, *b*, are constants depending upon the nature of the gas. It has been found that the values of the constants, *a* and *b*, depend upon the critical temperature and pressure of the gas. Therefore, the deviations from the law of ideal gases also depend upon the critical temperature and pressure. So we can use a correction factor or deviation that may be applied to the ideal gas equation to give correct results for actual gases, and this correction factor will be a function of the critical pressure and temperature.

The Residual Volume

The residual volume is the difference obtained by subtracting the actual volume of the gas from the volume computed by the ideal gas laws, and may be defined by the following equation, which gives the molar resid-

GEO. GRANGER BROWN

graduated with a bachelor's degree in chemical engineering from New York University in 1917—Served with the Aluminum Company of America at Massena, New York, with the Chemical Warfare Service at Washington, D.C., then as production manager for the Union Special Machine Company in Chicago, and Youngstown Sheet and Tube Company at Evanston, Illinois—In 1920 joined the staff of the Department of Chemical Engineering, University of Michigan —Post-graduate studies led to the doctor's degree received in 1924—The professional degree of chemical engineer was granted by New York University in 1925—In 1926 began investigation of the relationship between motor fuel volatility and engine performance as director of research for the Natural Gasoline Association of America—He has acted as consultant and technical expert for many of the leading oil companies and motor car manufacturers and has represented the American Petroleum Institute at legislative hearings—Was awarded the William H. Walker Award for 1939 for meritorious contributions to chemical engineering literature.

ual volume, (V), or the residual volume per lb. mole of gas:

$$(V) = \frac{RT}{P} - V \quad \ldots\ldots\ldots (3)$$

in which case N is unity and V is the actual molar volume, or the volume actually occupied by a weight of gas equal to the molecular weight in lb., and, (V), the molar residual volume, is the number of cu. ft. to be subtracted from the volume computed by the ideal gas law for a molecular weight of gas, in order to get the correct actual volume. The molar residual volume is therefore an additive correction that is subtracted from the ideal molar volume to obtain the actual molar volume.

The Compressibility Factor

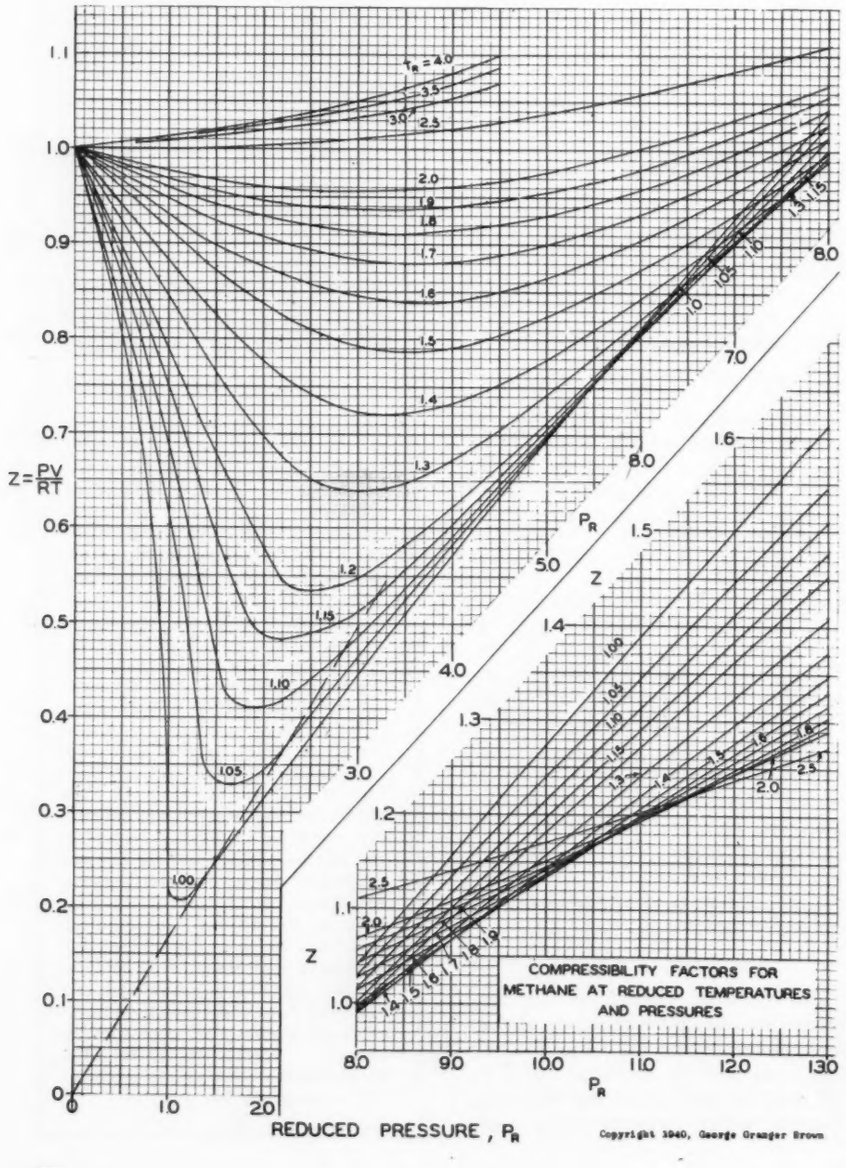
The compressibility factor is a multiplying correction factor by which the volume computed by the ideal gas law is multiplied to obtain the correct actual volume. It is defined as, Z, in the following equation:

$$PV = ZNRT \quad \ldots\ldots\ldots\ldots (4)$$

The relationship between the residual volume and the compressibility factor is expressed by the following equation in which N is unity:

$$(V) = \frac{RT}{P} - V = \frac{RT}{P} - \frac{ZRT}{P} = \frac{(1-Z)RT}{P} \quad \ldots\ldots (5)$$

Fig. 1. Compressibility factors for methane with graphical solution of Illustration 3



The compressibility factor is a dimensionless intensive factor independent of the extent or weight of the gas, and being a multiplying factor is a most convenient correction to apply to the ideal gas relationship to obtain correct values for gases under pressure. Like all correction factors its value depends upon experimental data for its determination.

The constants, *a*, and, *b*, in Van der Waal's equation remain constant for any particular gas over the entire range of temperature and pressure; but the residual volume, and the compressibility factor, are not constant for each particular gas but depend upon the temperature and pressure. From this one might conclude that Van der Waal's equation were simpler in application and generally more advantageous, but Van der Waal's equation is a cubic and for many applications this makes it very inconvenient. Furthermore, because the residual volume and the compressibility factor depend on temperature and pressure they can be tabulated or plotted for any particular gas to obtain any desired degree of accuracy, whereas Van der Waal's equation is still an approximation.

If it is necessary to plot Z or (V) as a function of temperature and pressure, however, as has been done for CH_4 in Fig. 1 based on the best available data, it would appear much simpler to plot volume or density directly as a function of temperature and pressure and get the answer directly as has been done for butane in Fig. 2. But such plots can be drawn accurately only for those gases that have been thoroughly and carefully investigated, and charts such as Fig. 1 in which Z is plotted as a function of reduced pressure, P_R, and reduced temperature, T_R, have a much more general and important function than serving simply as a means of determining the volume of that gas for which they are drawn.

As was suggested under Van der Waal's equation, the deviation of an actual gas from the ideal gas is a function of the critical temperature and pressure. According to the theorem of corresponding states this deviation is the same for different gases when at the same corresponding state. The same corresponding states are found at the same fraction of the absolute critical temperature and pressure, which are known respectively as the reduced temperature, T_R, and reduced pressure, P_R, defined as follows:

(6) Reduced temperature, $T_R = \frac{T}{T_c}$, the ratio of the absolute temperature at which the gas exists to its absolute critical temperature.

(7) Reduced pressure, $P_R = \frac{P}{P_c}$, the ratio of the absolute pressure at which the gas exists to its absolute critical pressure.

where T_c = the critical temperature, and P_c = the critical pressure. Therefore, if the theorem of corresponding states can be applied without appreciable error all gases would have the same value for Z at the same reduced temperature and pressure, and a plot of Z for methane as given in Fig. 1 as a function of reduced temperature and pressure can be applied to determine the unknown value of Z for some other gas if we know or can determine the critical temperature and pressure of the second gas. This is a most important relationship, which appears to be reasonably accurate for similar gases and, when properly used, for gaseous mixtures.

The reduced temperature and reduced pressure are each dimensionless and Fig. 1 is directly applicable for the determination of Z with any units of temperature or pressure, care being taken to use only absolute units of the same kind in determining reduced temperature and pressure. For example, if the critical temperature of a gas is minus 50°C. and the temperature at which the gas exists is known in °F., say 80°F., the reduced temperature is obtained by dividing the absolute temperature corresponding to 80°F. or 460 + 80 = 540, by the absolute temperature in Fahrenheit units corresponding to minus 50°C., which is (273 — 50) (1.8) = 401.4; giving $T_r = \frac{540}{401.4} = 1.345$. The same value for T_r is obtained by dividing the absolute temperature in Centigrade degrees corresponding to 80°F. or $\frac{(460 + 80)}{1.8} = 300$ by the absolute critical temperature of 223.

Similarly, reduced pressures may be determined either by dividing absolute pressure in atmospheres by critical pressure in atmospheres, or absolute pressure in lb. per sq. in. by absolute critical pressure in lb. per sq. in.

For best results estimates of Z for a gas whose properties are not known should be based on a plot derived from a gas of approximately the same molecular weight. Most natural gases are predominately methane, and Fig. 1 may be used with satisfactory results for all cases encountered in natural gas and most natural gasoline problems.

The use of the compressibility factor in making gas computations may be made clear by the following examples:

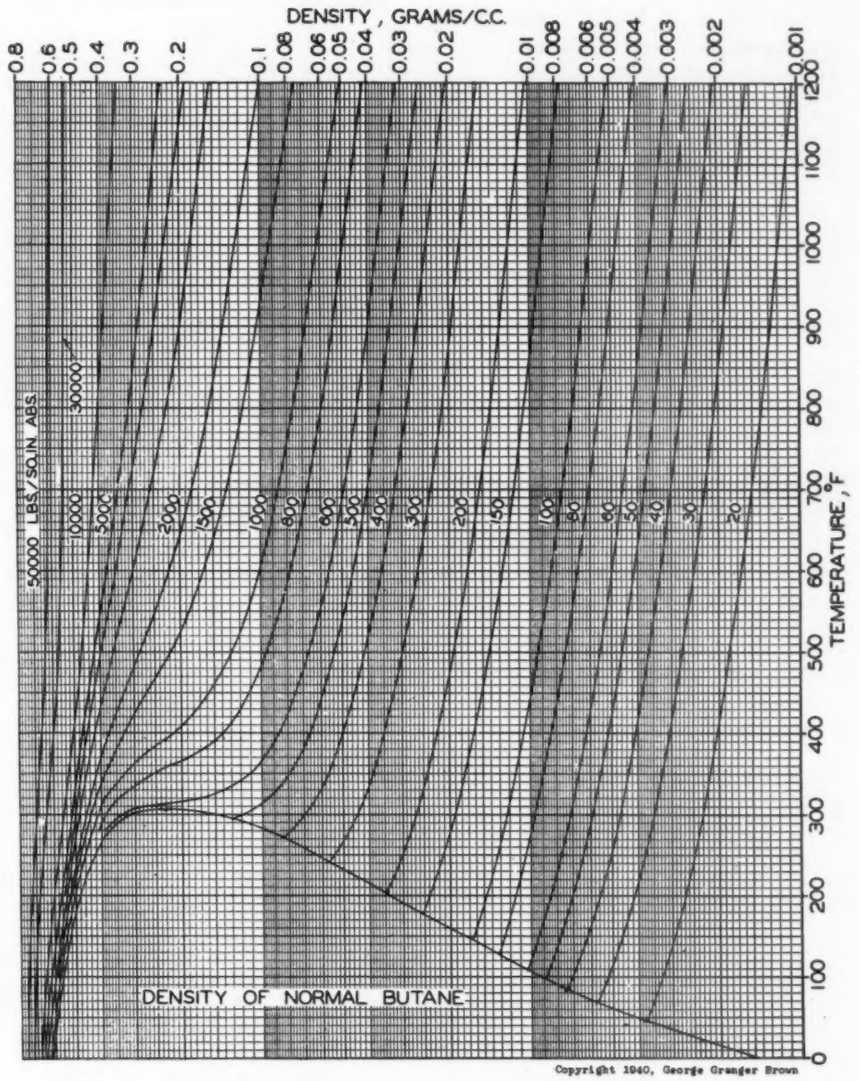


Fig. 2. Density of normal butane in grams per cc. or specific gravity of normal butane referred to liquid water

Illustration 1: Volume Unknown. Calculate the volume occupied by 1 lb. of ethane at 144°F. and 2000 lb. per sq. in. gauge pressure. From Table I the critical pressure is 712 lb. per sq. in. absolute and the critical temperature 549°R., therefore,

$$P_R = \frac{2000 + 14.6}{712} = \frac{2014.6}{712} = 2.83$$

$$T_R = \frac{460 + 144}{549} = \frac{604}{549} = 1.1$$

From Fig. 1; Z = 0.47

Molecular wt.; M = 30, $N = \frac{W}{M} = \frac{1}{30}$

Equation 4; $V = \frac{ZNRT}{P} =$

$$\frac{0.47 \times 10.71 \times 604}{30 \times 2014.6} = 0.05 \text{ cu. ft.}$$

Illustration 2: Weight Unknown. Calculate the weight of ethane contained in a cylinder of 0.5 cu. ft. capacity if the temperature is 144°F. and the pressure 2000 lb. per sq. in. gauge.

As for illustration 1: $P_R = 2.83$;

$T_R = 1.1$; $Z = 0.47$

$PV = ZNRT$

(2014.6) (0.5) = (0.47) (N) (10.71) (604)

$N = 0.33$

Weight, W = (N) (M)

$= 0.33 \times 30 = 10$ lb., *ans.*

Illustration 3: Pressure Unknown. Calculate the pressure that would be

reached if 10 lb. of ethane were charged in a cylinder of 0.5 cu. ft. capacity and the temperature rose to 144°F. Critical temperature and pressure as before from Table I.

$$T_R = \frac{460 + 144}{549} = 1.1$$

$$M = 30$$

$$N = \frac{W}{M} = \frac{10}{30} = \frac{1}{3}$$

$$P\ \frac{V}{NRT} = Z$$

$$P_R\ \frac{P_c V}{NRT} = Z$$

$$P_R\ \frac{712 \times 0.5 \times 3}{10.71 \times 604} = Z$$

$$P_R\ (0.166) = Z$$

This is the equation of a straight line of slope 0.166 passing through the origin when plotted on Fig. 1. When P_R is zero, Z is zero; and when P_R is 1.0, Z is 0.166. Extending this line until it intersects the line of $T_r = 1.1$, which is the required reduced temperature, we read 2.83 for P_R, or 0.47 for Z. Therefore, from equation 7, $P = 2.83 \times 712 = 2015$ lb. per sq. in. absolute and the gauge pressure is 2000 lb. per sq. in.

TABLE I

Present Best Values of Physical Properties of Natural Gas Hydrocarbons

Compound	Formula	Mol. Wt.	Density of liquid at 60°F. in grams per cc.	Normal boiling point, °F.	Critical temperature, °F.	Critical temperature, °R.	Critical pressure, lb. per sq. in. abs.
Methane	CH_4	16.04		−258.5	−116	344	673
Ethane	C_2H_6	30.07		−127.5	89	549	712
Propane	C_3H_8	44.09	0.510	− 43.9	205	666	617
n-Butane	C_4H_{10}	58.12	0.584	31.1	306	766	551
iso-Butane	C_4H_{10}	58.12	0.564	13.6	272	732	544
n-Pentane	C_5H_{12}	72.15	0.6304	96.9	386	846	485
iso-Pentane	C_5H_{12}	72.15	0.6241	82.3	370	829	483
n-Hexane	C_6H_{14}	86.17	0.6634	155.8	454	914	435
n-Heptane	C_7H_{16}	100.2	0.6875	209.1	512	972	397
n-Octane	C_8H_{18}	114.22	0.7064	258.2	564	1024	362

Fig. 3. Graphical solution of Illustration 4

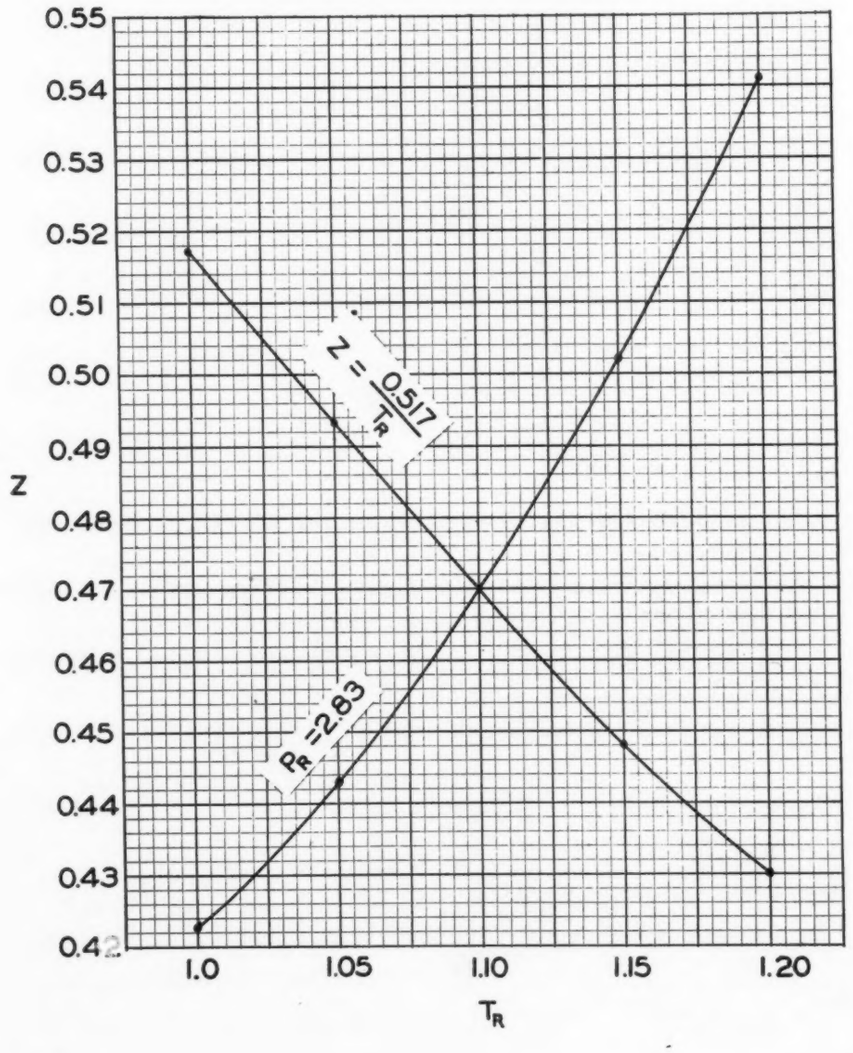


Illustration 4: Temperature Unknown. If the volume occupied by 10 lb. of ethane at 2000 lb. per sq. in. gauge is 0.5 cu. ft., calculate the temperature. As before, from Table I, $T_c = 549$°R; and $P_c = 712$ lb. per sq. in. absolute; therefore

$$P_R = \frac{2000 + 14.6}{712} = 2.83$$

$$T_r = \frac{T}{549}$$

$$N = \frac{10}{30} = 0.33$$

Equation 4: $PV = ZNRT$

$$(2014.6)\,(0.5) = Z(0.33)\,(10.71)\,(T)$$

$$Z = \frac{(2014.6)\,(0.5)}{(0.33)\,(10.71)\,T} = \frac{2825}{T}$$

$$Z = \frac{282.5}{549\,T_R} = \frac{0.517}{T_R}$$

The answer is that value for T_R which satisfies both the above equation and the relationship given in Fig. 1 for the reduced pressure, P_R, of 2.83. This may be solved by trial and error reading values of Z and T_R for a constant P_R of 2.83 from Fig. 1 until such values of Z and T_R satisfy the above relationship. Or a solution may be reached graphically by plotting Z as a function of T_R for $P_R = 2.83$ as has been done in Fig. 3, and also plotting Z as a function of T_R as obtained from the above equation. The intersection at $T_R = 1.1$, or $Z = 0.47$, is the desired solution. Since $T_c = 549$

$$T = T_R T_c = 1.1 \times 549 = 604\text{°R.} = 144\text{°F.}$$

Usually the temperature is known and problems such as illustration 4 are not encountered. If such problems are frequently encountered, the graphical solution can be made very simple by preparing a plot of Z as a function of $\frac{1}{T_R}$ with lines of constant P_R. With such a plot straight lines would represent $Z = \frac{A}{T_R}$ and the solution becomes as simple as illustration 3, where pressure is unknown.

P 511.222.
P 522.3

Bottom-Hole Well Regulators

By K. C. SCLATER
Editor, The Petroleum Engineer

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Pressure-operated bottom-hole chokes protect against freezing and permit greater flexibility in the operation of high-pressure gas and gas-distillate wells

FREEZING is a prevalent problem in high-pressure gas wells when the pressure reduction between the well and the line is very great.

One means of preventing or mitigating freezing is to make the required reduction in pressure in the well, either at the bottom of the tubing or at some point higher. One way of accomplishing this that has been practiced for years is by means of removable bottom-hole chokes. By placing the bottom-hole choke at some convenient point in the tubing in the well the cooling action resulting from the reduction of pressure across the choke may be effectively dissipated.

The cooled gas on its way to the surface draws heat from the walls of the well and thus its temperature is raised sufficiently to preclude the possibility of freezing. In large-volume high-pressure gas wells having a low bottom-hole temperature, it may not be possible to prevent freezing entirely during extremely cold weather when producing at high rates of flow.

Although this application of the bottom-hole choke to prevent freezing is being used successfully, it has limitations. In a well whose rate of production is subject to wide fluctuations, the conventional type of bottom-hole choke, which has a fixed opening, lacks flexibility. Having a fixed opening, the bottom-hole choke is thereby limited to use in gas wells whose rate of production is reasonably constant. When changes do have to be made in rate of production the bottom-hole choke, being removable, may also have to be changed. It is not always, however, convenient or possible to interrupt well operation; and for this reason the need has been felt for a choke of greater flexibility to cope with a wider range of well production rates.

The problem was to design a choke that would have all the desirable characteristics of the bottom-hole choke and, in addition, a greater capacity to handle wide fluctuations in rate of flow. A design that meets these requirements is that of the pressure-operated variable bottom-hole choke. The design is such that the choke has a capacity to regulate, within reasonably close limits, widely varying rates of flow. This new type of bottom-hole choke really functions as a bottom-hole regulator, the name by which this choke of improved design is known.

There is an essential difference between the bottom-hole choke and the bottom-hole regulator: The bottom-hole choke operates on a fixed opening, whereas the bottom-hole regulator operates on a fixed differential pressure, or pressure drop. The principle on which the regulator operates should be observed at the outset for it is the key to the successful application of this device.

Referring to the accompanying drawing, which shows the construction of the regulator, the essential parts are: an adjusting ring, an expanding spring, a movable valve seat, and the valve itself. The movable valve seat is opened by the spring, the tension of which is governed by the size of the adjusting ring.

The valve, it will be noted, floats on a light spring. The purpose of the light spring, which is a recent improvement added to the regulator, is to provide for killing the well if necessary, without having to pull the regulator, by pumping water or mud down the tubing.

In use the regulator is placed at any desired depth in the tubing and is set in the same manner as the bottom-hole choke. Before running the regulator the tension of the expanding spring is adjusted to the desired drop in pressure. The desired drop in pressure is determined by the shut-in pressure of the well and the pressure required at the surface choke or regulator. For example, if the shut-in pressure of the well is, say, 2500 lb. and a pressure of 1400 lb. is desired at the surface choke, the spring tension on the regulator is set for a differential pressure, or pressure drop, of 1100 lb. across the valve, and this setting is made before running the regulator into the well. The maximum pressure differential for which the spring can be adjusted is 1500 lb. This, it has been found, is the economic maximum pressure differential. The high velocity of the gas at differentials greater than this may cause excessive wear on the valve seat, necessitating frequent renewal. The valve and seat are made of a special metal that is highly resistant to corrosion and erosion. All the moving parts are entirely closed.

Operation of the regulator is simple and entirely automatic. The gas enters from the side ports shown. The expanding spring controls the valve opening and maintains the desired differential pressure across the valve. If the pressure drop is less than that for which the expanding spring is set, the valve seat closes on the valve. The regulator is usually used in conjunction with a choke or regulator at the surface. In extremely high-pressure wells in which a pressure reduction greater than 1500 lb. is required, two or more bottom-hole regulators may be used.

The regulator is run on a steel wire line and reel through a high-pressure lubricator with wire line stuffing box. The procedure and tools used in setting are the same as those used in setting a bottom-hole choke.

The estimated capacity range within which the regulator will operate is about 5,000,000 cu. ft. of gas per day; in other words, fluctuations in the rate of production of this amount

Surface Choke in.	Rate of prod'n M.F.C. 24 hr.	Tubing pressure lb./sq. in.	Temp. at Surface Choke—°F. Upstream Side	Temp. at Surface Choke—°F. Downstream Side
3/16	610	715	88	72
1/2	3075	520	85	76
*9/16	3700	490	85	76
Wide Open	4750	380	85	76

2-in. tubing
Regulator set at 1500 ft.
Closed well pressure, 2340 lb.
Differential pressure at well regulator, 1500 lb.

*With regulator set at 5000 ft., and producing at approximately this rate, the temperature of the production after passing through the surface choke was found to be 82° F. changing the position of the regulator from a depth of 5000 ft. to 1500 ft. resulted in a temperature loss of 6° F.

may be automatically controlled by the one differential pressure setting of the regulator.

Observations of the effect on temperature of the gas by setting the regulator high in the tubing rather than at the bottom are of interest. It has been found that the bottom-hole regulator in some wells has been set at as shallow a depth as 1500 ft. from the surface without causing a serious reduction in the surface temperature of the gas.

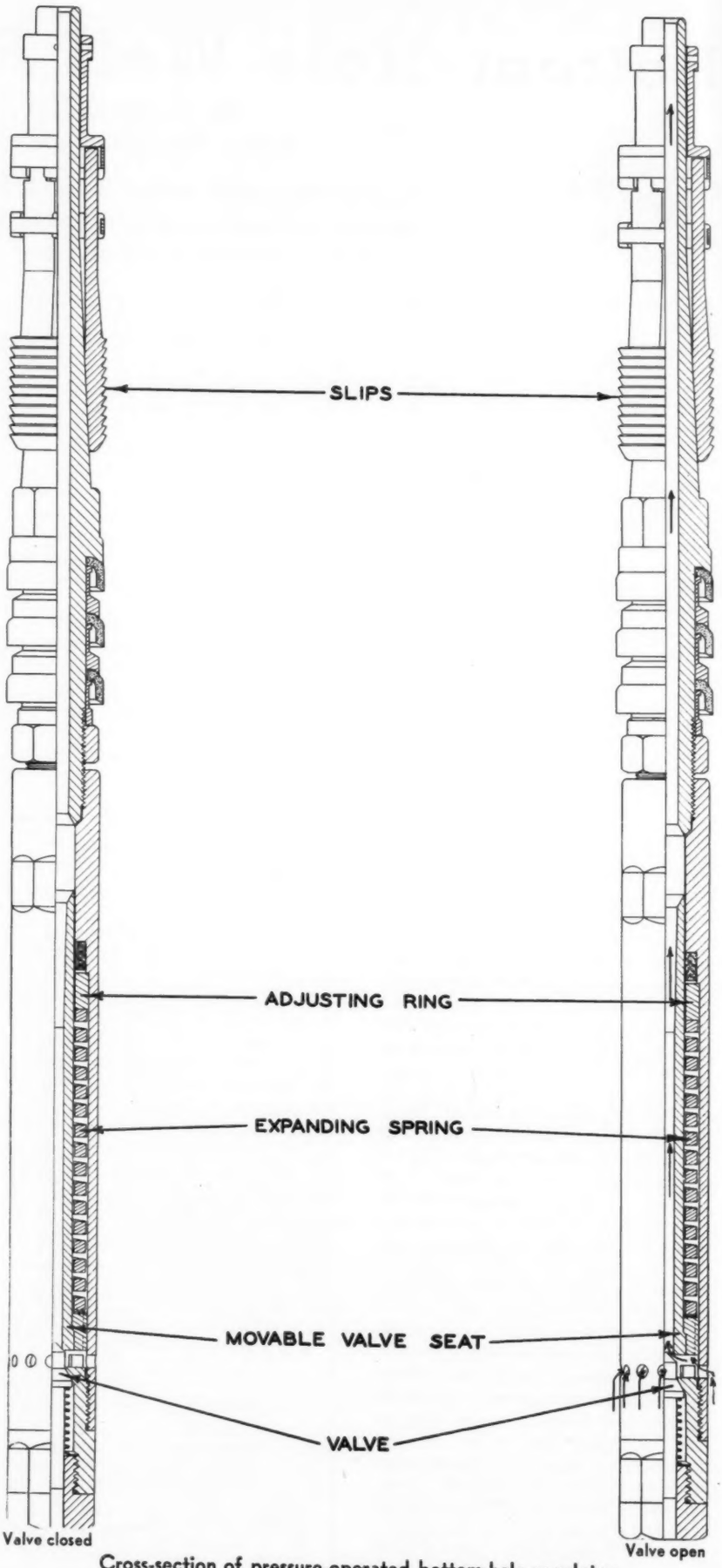
A record taken on the gas well is shown in the accompanying table. It was found that by moving the regulator up the hole from 5000 ft. to a depth of only 1500 ft. the temperature loss was only six deg. F. This well was feeding against a line pressure of 380 lb. It will be noted also that although the rate of production was increased from 3,075,000 cu. ft. a day at 520-lb. tubing pressure, to 4,750,000 cu. ft. at 380-lb. tubing pressure, there was no change in temperature at the upstream or downstream side of the surface choke.

On a distillate well, the regulator in which was first set at 4000 ft. and then later at 2000 ft., a difference in temperature of only two deg. F. resulted although the well was delivering in excess of 3,000,000 cu. ft. of gas and about 60 bbl. of distillate a day.

In the Cunningham field in Kansas, three wells equipped with bottom-hole regulators were among the few that did not freeze during a recent cold spell.

The close control obtained in deep high-pressure wells with these regulators makes for improved well operation and greater safety by eliminating violent fluctuations in pressure at the face of the sand.

In deep distillate fields these regulators have an application the value of which it is yet too early to appraise. Conclusive data on their operation and the results obtained by their use are not yet available. It is reported that the gas-distillate ratio has been reduced by the use of bottom-hole regulators, though to discuss this phase of operations would be premature, as the tests have not been exhaustive enough to yield any conclusive results. There are indications, however, that the use of bottom-hole regulators may have an important function in producing distillate wells. They show promise of being of substantial aid in promoting sound gas distillate production practice, involving as it does a consideration of the state in which hydrocarbons exist in the sand and at the bottom of the hole. In this field, particularly, does the regulator appear to have wide application.



Cross-section of pressure-operated bottom-hole regulator

P 515.1
P 111.343

Gas-Lift Practice In West Texas Fields

Gas-lift installations in wells are varied in type to meet conditions in West Texas fields — large volumes of water and low levels in wells are among problems confronted

By H. LEE FLOOD
Associate Editor

TO avoid, in the detailed discussion to follow, the impression that gas-lift is at the present time the only production method being employed in West Texas, it is important to survey briefly the status of production methods generally.

West Texas, considered as a whole, embraces as great a variety of production phases as does any area comprised of old and new fields. Wells in the relatively newer fields and even in a few of the older fields are still flowing "naturally." Others that no longer will flow satisfactorily unassisted are being produced by the judicious use of either flow valves or pumping equipment to utilize the energy of the remaining formation gas more effectively. Wells in fields where there is an inherent lack of formation gas or where the gas has been depleted are being pumped, or, in some instances, are being produced by gas lift utilizing gas from nearby wells completed as gas wells for the purpose of supplying gas for lifting purposes.

Wells in the Hendrick field where water must be produced in the rough proportion of 1000 bbl. to obtain 1 bbl. of oil are being produced either by casing pumps or gas lift, to be discussed later.

Finally, in those areas, principally in certain of the older fields, where production has declined to 5 or 10 bbl. per day in wells having low bottom-hole pressures and low productivity indexes, a production problem has developed that in itself is one of the more interesting to be found in West Texas. The South Ward field contains the best examples of this type of well and will be discussed fully.

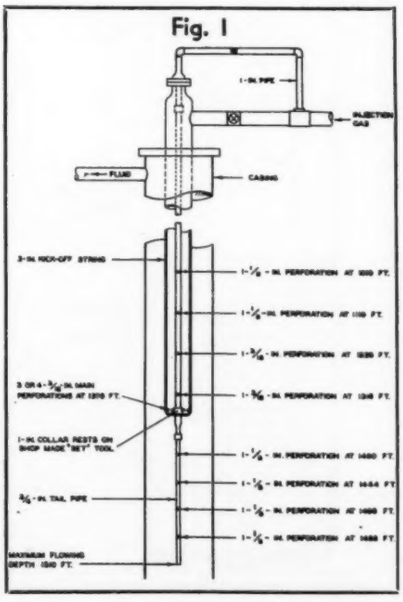
Gas-Lifting Large Fluid Volumes

Perhaps the greatest number of gas-lift installations devoted to a single type of service in West Texas is in the lifting of large volumes of water to obtain relatively small volumes of oil. Installations of this type are principally found in the Hendrick field, Winkler County. Production is from the "Big Lime" in which prolific oil production in the early life of the field was the result of the high hydrostatic head exerted by the large volumes of water underlying the oil. Brought-in in 1928 when the general practice was still to produce wells "wide open," the wells in the Hendrick field soon began producing more and more water as water-coning became more pronounced.

Almost without exception, wells in the Hendrick field when they had ceased flowing were equipped with pumping units. As fluid volumes increased, casing pumps were installed. Many of the wells in the field are still pumping but as the ratio of oil to water decreases and the required fluid volumes exceed the capacities of the largest pumps, the wells have been converted to gas lift. As the volume of gas produced with the fluid is almost negligible, gas for lifting purposes is obtained from gas wells completed in overlying sands in the Hendrick or nearby fields. After the gas has been utilized to lift the fluid it is not economical to conserve it for any further use.

The predominant characteristic of the large fluid-volume wells in the Hendrick field is the high static level of the fluid, usually 200 to 250 ft. from the wellhead. The working fluid level, however, is from 1200 to 1400 ft. from the wellhead. An essential feature of any gas-lift installation consequently must be the ability to kick-off the high fluid column and then produce efficiently the large volume of fluid. Flow valves of the differential- and velocity-control types have, therefore, been used extensively in this service. It is a tribute to the equipment now available that virtually every flow valve on the market is employed somewhere in the Hendrick field.

Fig. 1

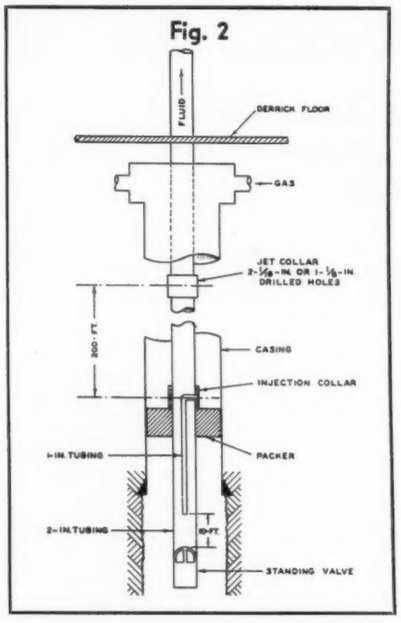


Many of the flow-valve installations are conventional and will not be discussed in detail except to mention that it is usually conceded by engineers in the field that the many alterations and changes are due not so much to inherent faults of the flow valves as to the ever-changing flow conditions within the wells themselves. An installation may be adjusted to operate satisfactorily at the fluid working level then prevailing and a week later the working level may suddenly subside or even rise without apparent cause and require complete re-adjustment of the gas-lift equipment. This variability, of course, usually characterizes production from limestone formations.

These conditions plus the very urgent requirement that labor, equipment, and other charges entering into the total lifting cost be maintained at a low figure dictate largely the practice that is followed. The surprising thing is that the wells can be produced at any profit at all when so much fluid must be produced. It is here that gas lift has proved its value because it is conceded that no other method could permit wells to be depleted to 3 and 5 bbl. of oil per day as is being done economically in the Hendrick field. Excessive lifting costs occasionally dictate the abandonment of a well, but usually the limit is determined by inability to maintain the input gas-oil ratio below the legal limit of 10,000 cu. ft. per bbl.

Skillful Engineering Essential

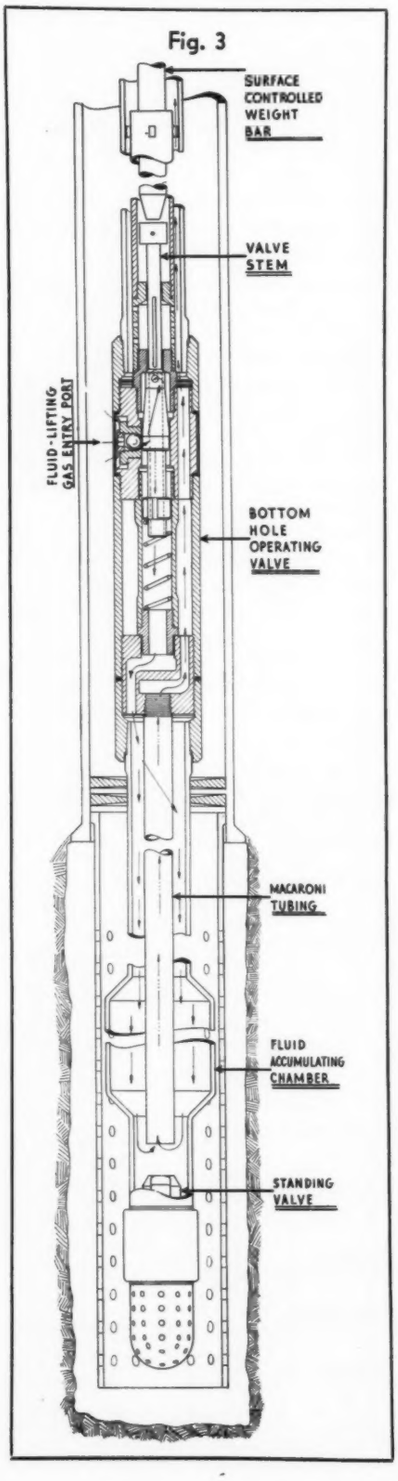
Skill and judgment on the part of



the engineer as the essential factors in obtaining efficient gas-lift performance is emphasized nowhere so strongly as in West Texas. Ingenuity has been shown in the methods by which engineers with the oil companies and gas-lift equipment manufacturers have incorporated new ideas to meet the specific conditions encountered. This effort to cope with the problems of the area has even taken the form of designing installations employing only standard pipe and fittings, usually to maintain equipment investment as low as possible in order to obtain low lifting costs.

Combination tubing strings are being used extensively in the Hendrick field in order to lift excessive fluid loads when necessary. Some installations employ manufactured flow valves or jet collars but the installation shown in Fig. 1 employs only standard tubing and couplings field-perforated as jet collars. The "set" tool may be a swedge or a steel plate or any other suitable device easily obtained in the field. This installation has been selected from the many types in use because it represents the practice of one leading company operating in the Hendrick field and is employed by another company in the field with little difference except that a leather-packed working barrel having the valve omitted is used as a packer between 1¼-in. and 3-in. tubing strings instead of the set tool. In the sketch, the depths shown for the perforated collars apply to the specific well selected as a representative installation. This well is producing 7500 bbl. of fluid to obtain 70 bbl. of oil. The volume of input gas required is 550,000 cu. ft. per day at 450 lb. pressure, a unit volume of 7860 cu. ft. per bbl. of oil.

In operating an installation of this type, gas may be introduced into the annulus between the 1-in. and 3-in. tubing strings to unload the well and then in normal flow the gas enters through the 1-in. and is admitted to the casing through the perforations in the ¾-in. tail pipe. The lower end of the ¾-in. pipe is closed slightly to restrict the passage of gas. This type of



device is being used satisfactorily to lift 7000 to 10,000 bbl. of fluid per day. The admitted inefficiency caused by the gas escaping constantly through the upper perforations is offset by the additional lift imparted as the fluid ascends. The installation is of the open type in that no packer is used to close the casing-tubing annulus.

In the south part of the Hendrick field where low fluid levels are encountered and in certain wells in the Kermit and Estes fields having low productivity indexes, one company is employing the installation shown in Fig. 2. A packer and a standing valve are used to prevent input gas pressure reaching the formation. Used in intermittent operation only, the injected gas evacuates the tubing string effectively to within 10 ft. of the standing valve. The principal purpose of the drilled jet collar in the tubing string 200 ft. above the injection collar is to insure equalization of pressure between the tubing and casing to prevent excessive back pressure on the standing valve in the event the open end of the 1-in. tubing becomes submerged too quickly. The constant escape of gas through the jet collar serves to lighten the fluid column as it is lifted.

Wells in the Kermit and Estes fields where this installation is proving effective have bottom-hole pressures of 730 and 525 lb., respectively, but the productivity indexes are low and it is important to maintain back pressure on the formation as low as possible.

Low Fluid Level, Low-Pressure Wells

Typical of older West Texas wells producing from sandstone formations is the low bottom-hole pressure now prevailing in some areas and the consequent low fluid levels in the well-bore. Whether all sand production in West Texas will be of this general type in the later stage of productive life it is too soon to say but the evidence thus far is indicative of this. Another characteristic of sand wells in West Texas in which much interest has been shown is the loosely-consolidated sand that seriously interferes with steady production by filling up the well bore and often sanding-up the production device.

Although the general problem as discussed here is found to some extent in other West Texas fields, it is principally to conditions in the South Ward field that the remarks will be confined.

Wells in the South Ward field are usually equipped with 7-in. casing set at a depth of approximately 2200 ft. The total depth of the wells is about 2600 ft. The 400 ft. below the casing may contain a 5½-in. liner, but

more often the well is open to the formation. Oil production in the central part of the field is from the Penn-Bennett formation; gas is produced from the so-called Grand Falls sand. The loose sand is not so much from these producing formations as it is from the other sand zones alternately occurring throughout the exposed section. Perforated liners are usually not very effective in holding back the sand because of its floating tendency.

After many experiments with various types of both pumping and gas lift equipment, surface-controlled intermitters are found to give satisfactory service.

Two types of wireline-operated, surface-controlled, gas-lift systems are being used. Both systems are of the closed intermittent type utilizing a tubing packer above the casing seat. Below the packer, tubing is run to the bottom of the hole with a standing valve placed above the lower perforations, or if run open-ended, at the bottom of the tubing. Inside the main tubing, a macaroni string is run below the intermitting valve to a point within a few inches of the standing valve.

The two systems differ in many respects. In one type, unloading valves are spaced at regular intervals in the tubing string and a bottom-hole operating valve is placed immediately above the packer. The unloading valves are used to exhaust the fluid from the annulus between the tubing and casing after the packer has been set, thereby eliminating the necessity of swabbing the well in order to place it on production. The unloading valves are also used to start flow again in the event the well is off production a few days and the casing becomes loaded with fluid. Both the unloading valves and bottom-hole operating valve are mechanically opened from the surface by a weight bar suspended on a heavy single-strand wire line.

After the casing has been unloaded, the weight bar is spaced immediately above the bottom-hole operating valve. It is raised and lowered intermittently by a piston suspended directly above the tubinghead. As the piston raises, the heavy spring within the bottom-hole operating valve opens the gas ports, which allows the gas to enter the valve body, from which it passes outward into the annulus between the main tubing and macaroni string below the packer. The high-pressure gas admitted forces the fluid down and around the bottom of the macaroni string, through which it passes upward into the main tubing above the valve. This action may be traced in the sketch of the device shown in Fig. 3.

The mechanical intermitter at the surface controls the raising and lowering of the wire-line and weight bar. The piston suspended above the wellhead is raised by gas pressure introduced into the cylinder at predetermined intervals, and its lowering is controlled by the velocity of the fluid at the instant it reaches the surface. As the valve at the bottom of the hole is always held open until fluid reaches the surface, fluctuations in casing pressure are not important.

Slippage of gas through the fluid is held at a minimum with this system as the operating gas passes downward through the annulus between the tubing and macaroni string, and forces the fluid up through the small pipe into the main tubing above the valve.

The other type wireline-operated valve is also run immediately above the tubing packer. In this system only the bottom valve is used, with macaroni tubing extending downward from it to a point within a few inches of the standing valve. As unloading valves are not used with this system,

Fig. 4

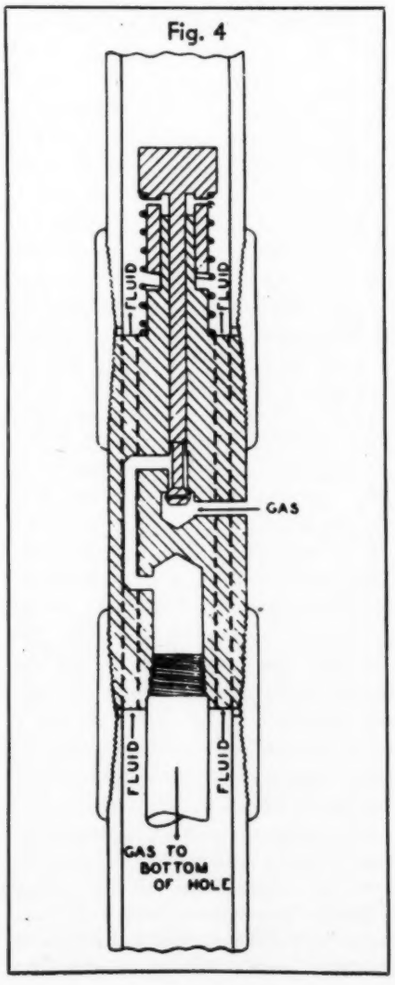
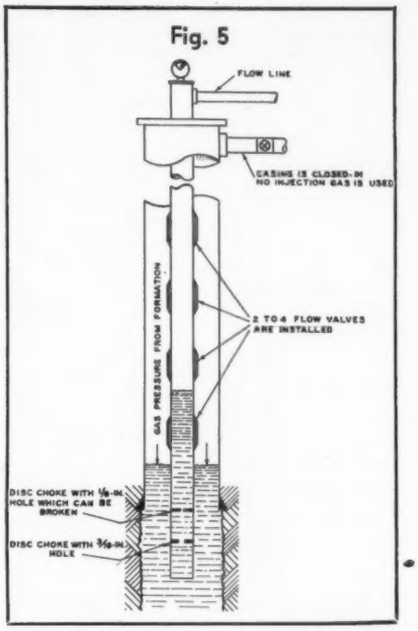


Fig. 5


FLOW LINE
CASING IS CLOSED-IN NO INJECTION GAS IS USED
GAS PRESSURE FROM FORMATION
2 TO 4 FLOW VALVES ARE INSTALLED
DISC CHOKE WITH 1/8-IN. HOLE WHICH CAN BE BROKEN
DISC CHOKE WITH 3/8-IN. HOLE

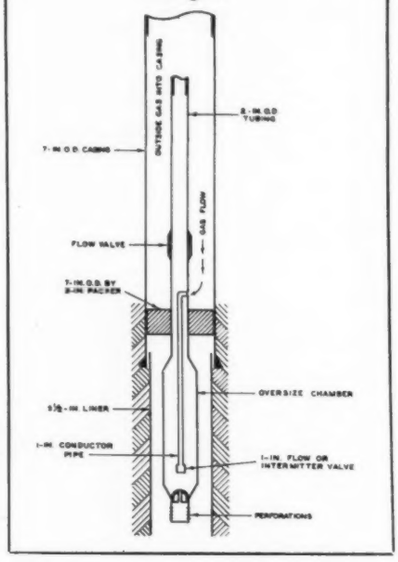
it sometimes may be necessary to swab the well down before putting it on production, unless high pressure gas is available at sufficient pressure to kick the well off around bottom.

The design of the bottom operating valve as shown in Fig. 4 is such that the gas is directed down through the macaroni string, and the fluid is produced upward through the annulus. This direction of flow is very efficient through the annulus between macaroni and small tubing, but may tend to produce slippage when large fluid accumulating chambers are used.

As in the other type system, the valve is opened and closed by a weight bar suspended on a wireline. The valve used with the first type system mentioned opens, however, on the upstroke of the intermittently-controlled piston. In the second type, the valve opens on the downstroke. Instead of employing the automatic fluid release, the intermitter used is fully time-controlled. It is set to open the valve in the bottom of the well at fixed time intervals, and also set to hold it open for a period of time sufficient to pass the required volume of gas to produce the fluid; therefore, because the valve is only held open for a set time interval, it is important that the casing pressure be constant.

Both intermitting systems described are working satisfactorily in Ward and Winkler County installations. Records since the intermitters have been installed show that downtime has averaged about 3 percent during the last two years, a remarkable record considering the great amount of lost time and expense in-

Fig. 6



curred in cleaning-out wells prior to their installation.

The principal advantages of intermitters of this type are (1) high velocity of the gas or fluid sweeping the chamber above the standing valve, thus keeping the sand in motion and producing it as it enters the tubing; (2) the ability to lift from bottom in sub-packer installations permits a satisfactory oil volume to be produced without the necessity of maintaining a static head of oil between the standing valve and the packer, and (3) the positive control of the gas injection interval enables a close adjustment of the gas volume to the amount needed, thus conserving on gas consumption.

Another type of installation being used in certain wells in the Keystone field, Winkler County, is shown in Fig. 5. The wells are being produced by gas lift utilizing the energy of formation gas collected in the annulus between the casing and tubing. The essential feature of the installation, aside from the flow valves that are used, is the one or more choke disks used to retard the rate at which fluid is admitted to the tubing. No packer is used and the fluid column in the annulus must be depended upon as a seal to prevent the gas being dissipated by passing into the tubing. Prior to the installation of the choke disks and because the productivity indexes of the wells are low, each time a load of oil would be lifted in the tubing by successive operation of the flow valves, equilibrium between the tubing and casing would be reëstablished by the inrush of oil from the casing into the tubing rather than from the formation, quickly resulting in the ejection of all the fluid in the annulus above the bottom of the tubing and permitting the gas to blow-by and be lost. The simple expedient of restricting the flow of fluid into the tubing by means of the choke disks permits the fluid in the tubing to be replaced from the formation rather than from the casing by imposing a rate more nearly equal to the productive capacity of the formation. In the initial adjustment, a number of choke disks may be used, increasing the orifice size from the top downward. If the smallest disk proves to offer too much restriction, it may be knocked-out by a tool lowered-in from the surface. Likewise, successive disks may be removed until the rate of flow is satisfactory.

Another type of sub-packer installation used extensively throughout West Texas in wells having extremely low bottom-hole pressures is shown in Fig. 6. Employing a packer and a standing valve to prevent input-gas pressure from being exerted on the formation, an accumulation chamber may be used as shown or omitted in wells where the formation pressures are higher and the reduction of back pressure against the formation is not so essential. The flow valve above the packer serves as an unloader but normal operation is usually obtained through the sub-packer valve, which may be any one of several on the market designed to admit gas outward from a tubing string into a larger string of tubing or casing.

Fig. 7 is a sketch of a simple installation being used effectively in West Texas in intermittent operation. Of the straight-lift type employing an open-ended macaroni string within a 2-in. or 2½-in. tubing string equipped with an accumulation chamber and a standing valve, the intermittent feature is imparted by a time-cycle controller adjusted to operate as often and for as long a period as is warranted by the characteristics of the well and/or the daily production desired. Incidentally, one or two installations of this type have been made, employing a series of telescopic collars or valves in the inner string, actuated by lowering or raising the tubing at the surface. This affords a means of unloading the tubing in wells capable of accumulating a high column of oil.

One other interesting arrangement that is being used in open-lift installations in West Texas utilizes a time controller to intermit gas to a conventional flow-valve installation with the volume of admitted gas closely controlled to do the work necessary and no more, thus conserving gas consumption but more important, preventing the gas from blowing-by the bottom of the tubing and interfering with the steady production from the formation.

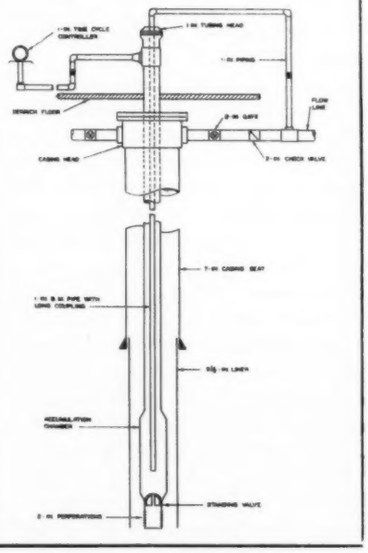
Lifting by "Braden-Heading"

In certain instances throughout the West Texas area, operators have been able, by suitably packing-off overlying gas sands, to use the energy of the gas to lift oil from the well either in continuous or intermittent flow, employing straight gas-lift or flow valves as warranted.

Of this type of installation are those in which the high-pressure inert gas occasionally encountered in the Yates sand is used as a lifting medium.

Gas lift in West Texas is being practiced extensively with installations ranging from conventional types to new applications, some incorporating new principles, others reverting to the earliest and simplest arrangements known. The methods selected here for discussion represent what are believed to be the more interesting and more representative of the many in use in the area. Widespread as the use of gas lift is at the present time, it is believed that a more extended use of gas-lift principles will come in the future as the many wells now flowing decline and require artificial lifting of some kind. Many of these wells produce little or no gas and this deficiency of a lifting medium will undoubtedly influence the selection of the type of artificial lift employed.

Fig. 7



The Technology of Refining Processes

Article 1

THERMAL CRACKING

By

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INTRODUCTION

THE primary operation in petroleum refining is and has always been—distillation. From the first crude "pots" in Pennsylvania, erected over the simplest of brickwork fireboxes, having a simple "gooseneck" vapor line and as simple a bent coil immersed in a wooden, water-filled tank, employing locally-mined coal as fuel, distillation methods and their development have been the chief concern of the refiner, in separating the chemically labyrinthine mazes of this unbelievably complex mixture of hydrocarbons.

Distillation fundamentally is merely the vaporization of a material, normally a liquid, and the condensation of the vapors to liquid again. The definition of simple distillation does not involve the careful separation of the vapors into narrow-boiling fractions, nor does it imply any chemical or molecular change in the products distilled. It is a purely physical operation by which, in practice, a mixture of liquids of different boiling points may be separated more or less crudely from each other or from non-volatile impurities that we desire to eliminate from the final product. In this connection an impurity, according to an old and widely experienced rule-of-thumb refinery operator, is "anything that is found somewhere where we don't want it."

Originally the Pennsylvania refiner distilled crude petroleum to obtain "coal oil" or kerosine; the lighter gasoline was a nuisance and the condenser was often run "hot" in order to eliminate this wild material, which caused lamps to explode and tended to bring the new type of household illuminant into disrepute because of the danger of using it. Kerosine competed then with the older coal oil, obtained in the same region from the destructive distillation of coal, and the coal oil salesman built much of his selling argument around the danger involved in the use of this new-fangled, ill-smelling stuff made from "rock oil."

This condition of affairs forced the oil refiner to get rid of the "wild" portion of his kerosine, and gradually was developed the next step in the technology of the separation of petroleum components—fractionation. Fractionation is the operation of separating any desired product or products from a mixture, usually into predetermined, relatively very narrow boiling-range fractions from which commercial products may be refined. The separation is on the basis of boiling range entirely. The earliest "fractionators" were merely open, cylindrical columns, and the heavier vapors ascending from the boiling liquid in the still were in part condensed and dropped back to be revaporized; this column gave only the most rudimentary fractionation, and this system was followed rapidly by the baffled tower, the packed tower filled with chain, brick, specially designed rings, blocks, etc., until the present almost universally used bubble-plate tower was developed, borrowed in great measure from coal-tar and alcohol distillation practice, and adapted to the peculiar needs of petroleum fractionation. The principle of all fractionating towers is intimate and repeated contact between down-flowing condensed liquid and up-rising vapors, enabling the vapors to rob the condensed liquid of its lighter fractions and carry them upward as vapors, at the same time condensing the heavier fractions of ascending vapors to mingle with the down-flowing condensate.

The other fundamental principle in refining technology is chemical purification. In its simplest form as most widely used in earlier practice it consisted almost entirely of treatment with sulphuric acid or of filtration through bone char, decolorizing earth, or similar agents. Sulphuric acid combines chemically with olefins, aromatics and other components, dissolves asphaltic and other materials such as resinous bodies, sulphur-, nitrogen- and oxygen-containing products, and for decades was the almost universal refining agent on light and heavy distillates alike. Filter agents remove color bodies by adsorption, as well as resinous and similar impurities. Beyond the fundamental concept of adsorptive filtration, the action of these agents is not too well understood.

Only recently two new principles have been introduced into the technology of petroleum refining. One of these is another method of separating crude oil into its components by differences in solubility of different types of compounds in a solvent immiscible with a raw petroleum fraction, or with

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after receiving bachelor's and master's degrees in organic chemistry from the University of Texas, in 1922 became affiliated with the research and development division of the Gulf Refining Company, where he remained until 1925—From 1925 until 1929 he was with the Petroleum Division, U. S. Bureau of Mines, at San Francisco, California, in charge of the chemical research laboratory—During that period, 1927-29, he was assistant to the chief engineer, Petroleum Division, Washington, D. C.—From 1929-39 was technical editor of *The National Petroleum News*, Cleveland, Ohio—In 1939 joined the staff of The Lubri-Zol Corporation as sales engineer, having as his field of activity lubricants and lubricant-treating methods.

which different components are miscible in widely varying degrees. Solvent extraction is applied both to light fractions such as kerosine and in a few instances gasoline, and to heavy lubricating oil fractions. This development will be discussed in greater detail in a later article.

The fourth principle in refining may be termed molecular change of petroleum hydrocarbons. Changes produced by the operations mentioned are physical and presume no appreciable rebuilding of the chemical structure of the products. Molecules as found in the crude material are found also unchanged in the final products, or are eliminated by chemical treatment and removed from the product. Since Dr. Burton in 1912 started his first crude cracking operation, the refiner has used more time, money, and ingenuity in the development of cracking processes than in any other phase of refining. Cracking still is the most important operation in the petroleum refinery and in its numberless ramifications will doubtless maintain that position for decades to come. Cracking has been amplified in very recent years by the remarkable developments of polymerization or the combination of smaller, olefinic or unsaturated hydrocarbons to form larger molecules; alkylation, the combination of olefinic with paraffinic or saturated hydrocarbons, also to form heavier molecules of the same or different types; aromatization, the rearrangement of aliphatic or straight-chain saturated molecules to form molecules of the unsaturated benzene type; isomerization, or the conversion of straight-chain paraffins to iso-paraffins; hydrogenation, the decomposition and rearrangement of molecules, usually heavy products, to form molecules of radically different chemical structure, with the addition of hydrogen to give more saturated products of the chemical composition and properties desired; and some other *-ations* all of which have as their primary result the rebuilding or rearrangement of molecular structures to obtain materials with more desirable properties.

This very brief introduction does not take into account the innumerable variations in refining processing that have come into practice in recent years. We are pointing out the primary, fundamental principles around which the technology of this most modern of all industrial developments is built. The application of these principles to refining, to the manufacture of commercial products, will be discussed in later articles in as great detail as space limitations will permit.

MODERN CRACKING TECHNOLOGY

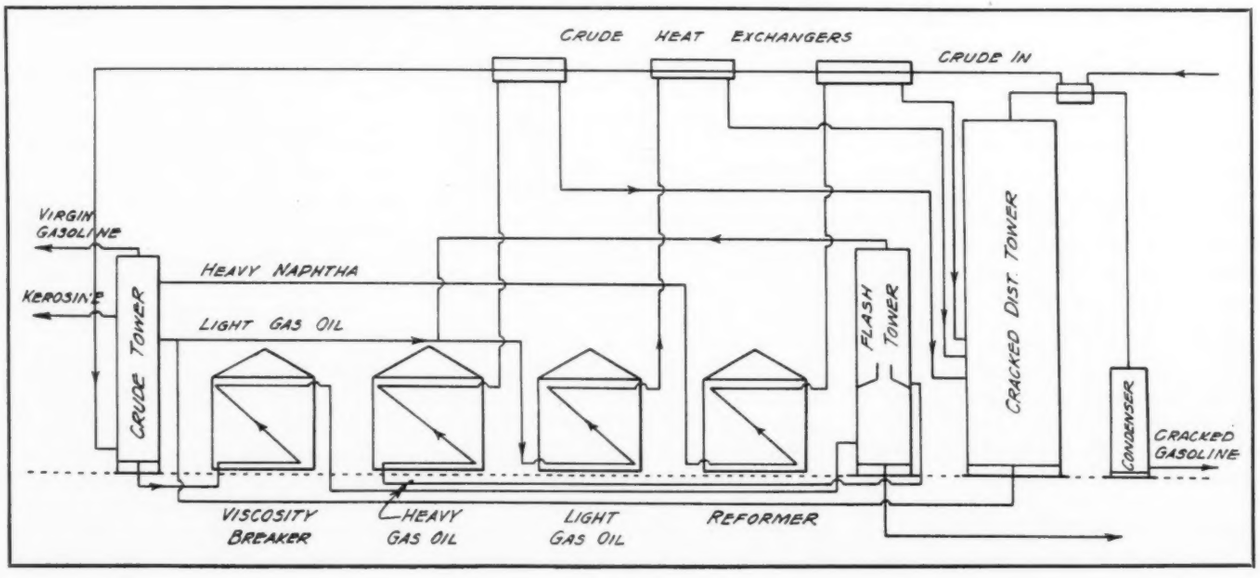
As stated in an earlier paragraph cracking is the most important operation in modern refining. For the uninitiated the term "cracking" may be taken somewhat literally, indicating the breaking up of heavy molecules to form those of lower molecular weight, identical in principle in the minds of the earlier less technically minded operators to the action of a crusher on stone.

A. Thermal Cracking

Cracking, however, in practice involves a general decomposition, rearrangement, dehydrogenation, hydrogenation, and polymerization of the charging stock. Clearly indicative of the presence of all these reactions is the result of heating any given charging stock such as gas oil under elevated pressure and temperature in a still without permitting any material to escape from the system. Beginning with a stock of boiling range, say, 400 to 675°F., the resulting cracked mixture in the still after a few hours' heating at 900°F. or higher will have a boiling range from 100°F. or lower to heavy asphaltic materials that cannot be distilled without decomposition, even at reduced pressures. Thus cracking produces both lighter and heavier products, and in earlier days the term "synthetic crude" was applied to the mass of liquid so formed under pressures and temperatures higher than atmospheric.

Three major factors affect and control cracking operations—pressure, temperature, and time of exposure of the charge to these conditions. Increase in the value of any of these factors increases the degree of cracking obtained. The rate of cracking per unit of time is doubled for each increase in temperature of 15 to 20°F., researchers have found, maintaining pressure and time constant. This value is variable, sometimes being less at higher temperatures or pressures. Therefore, to obtain a 20 percent yield of gasoline per pass through the system on a given charge stock in a given time, a cracking unit may be operated at 960°F.; to double

Fig. 1. Simplified flow chart of 4-coil combination cracking unit



this rate in the same time a temperature of 975 to 980°F. might be employed. Correspondingly, maintaining the stock at higher pressures or for longer periods of time increases the amount of cracking "per pass." To increase the time factor and the amount of cracking and at the same time to prevent the deposition of carbonaceous matter in the heating coils, reaction chambers are employed in which the heated charge is held at a predetermined temperature, to give the desired time of exposure of charge to the pressure and temperature needed to crack it to the desired degree.

In modern cracking the terms vapor-phase and liquid-phase, formerly used to differentiate between cracking that occurs with oil in the vapor state and in the liquid state, respectively, are somewhat misnomers, as both types of operation are intermingled in present-day practice. Some purely vapor units are now in operation as will be described later. More generally the term mixed-phase may be applied to most cracking operations at present, wherein cracking under both liquid- and vapor-phase conditions are employed.

Two main operating principles govern cracking as we know it today. One is the principle of recycling charge stock; that portion of it which has not been sufficiently cracked to the desired boiling range or which does not possess the desired degree of anti-knock properties is pumped back through the heating coils repeatedly, after the fractionating system has removed the portion that has been adequately cracked after each pass through the heater-reaction chamber system. The percentage cracked in each pass with any stock is limited by the amount of gas formed, the quantity of coke deposited, and the properties of the gasoline desired, the amounts of coke and gas being increased with increases in time, temperature, and pressure. Therefore experience has shown that cracking a relatively small percentage per pass with reduction in coke and gas losses, and the maintenance of clean heater coils, is preferable to high cracking percentages and the increase in these losses and early clogging of coils by coke with resultant earlier and more frequent shutdowns for clean-outs.

Optimum cracking rates per pass for different stocks are stated by Smoley and collaborators (*National Petroleum News*, Sept. 8, 1937, page R-159), to be as follows: viscosity-breaker stocks, 3 percent to 10 percent; heavy virgin and heavy refractory stocks, 10 percent to 18 percent; light virgin and light refractory stocks, 14 percent to 30 percent. These three groups of products correspond to heavy residual and recycle stocks, as reduced crudes and recycle bottoms; heavy gas oil and heavy overhead recycle stocks; light gas oil and/or heavy kerosine bottoms and recycle stocks of similar gravity or boiling range.

Assuming a crack-per-pass rate of 20 percent, then theoretically it will require five trips through the cracking unit to crack all of any given quantity of fresh stock introduced at any given time. Actually this does not occur, as the rate of cracking recycle stock is lowered by each pass, the recycle stock becoming more and more refractory and "dirty," charged with carbonaceous material until at last it is reduced to coke in a special unit or operation. Or it is included with other heavy, foul residual stock as heavy fuel oil, it being no longer economic to pollute the fresh stock with it or to heat it further because of the reduced yields of gasoline obtained.

In practice the percentage of recycle stock to fresh stock in the charge going to a cracking coil may range from ratios of 2 to 1 to about 5 to 1; even higher proportions are sometimes used, depending upon the specific conditions or on the products or yields desired. That is, fresh stock must be added to the recycle continuously to replace the amount of charge removed by cracking to gasoline, and the amount of very heavy residuum drawn-off to fuel oil or reduced to coke. The amount of stock converted to gasoline, plus the amount of heavy uncrackable residuum pumped away as fuel oil may be considered by the operator to total 50 percent of the charge. Then only 50 percent of the original stock is recycled, and to maintain the charge rate to the still an equal amount of fresh feed must be added continuously. Thus the ratio of total feed to fresh feed added at any instant is 2 to 1. If only 25 percent of the total charge—fresh plus recycle feed—is cracked per pass, and 5 percent of the heavy residuum is removed, a total of 30 percent, the ratio of fresh feed to total feed is 3⅓ to 1.

The second principle employed almost universally in modern cracking is that of multi-coil selective cracking. A topped crude, for example, is divided into two or more fractions in an atmospheric pressure tower. Each fraction requires different temperatures and pressures, different times; that is, throughput rates, different recycle ratios, to obtain the best yields of the best quality product. Cracking the whole mass under the same conditions in the same coil would result in over-cracking the less refractory portions and under-cracking the more refractory fractions, with increased loss in yield and quality in both cases. Therefore separate coils are employed for each charge stock, light gas oil, heavy gas oil, kerosine bottoms, heavy residual stock, and even for reforming straight-run naphtha fractions. Each is operated under such temperatures, pressures, and charge rates as experience has shown best for each particular stock, as will be outlined later.

The highest level of development of the modern cracking unit is the so-called combination topping-cracking system in which the raw crude is introduced, is broken into its various fractions and these portions either sent "as is" to the treating plant, or are cracked in their several coils under optimum conditions. This is a continuous process, heat exchange is used to a maximum degree to reduce operating costs.

A typical three-coil unit will be described. No attempt will be made to differentiate between the processes developed earlier under the names of Dubbs, Cross, Holmes-Manly, and others. The major principles used in each are identical, different methods varying chiefly in relatively minor details, which are important only when studying their operation in meticulous detail.

A 14,000-bbl.-per-day unit recently built charges a well-known mixed-base crude. The raw crude is introduced to the system through heat exchangers, picking up heat in turn from overhead gasoline vapors, kerosine or gas oil sidestreams, cracked charge on its way to reaction or flash chambers, and heavy residuum from the flash chamber that is on its way to cooler and fuel oil tanks. This charge may reach a temperature of 500-650°F. without an ounce of fuel being burned directly to heat it, merely absorbing the otherwise waste heat in products already heated. Or, it may pass finally through a simple, short heater coil and receive additional heat from combustion gases, if the exchange heat available is not enough to effect the temperature desired. The crude so heated is flashed into a fractionating tower, so controlled that a light straight-run gasoline fraction is vaporized overhead and condensed, to be treated and commingled with the cracked distillate obtained later. Kerosine, one or two streams of gas oil, are taken from the side of the tower as condensed at different points, "stripped" to remove too-light portions condensed with the heavier material, and are pumped to their respective cracking coils, or may be sent to storage for refining and sale as such. A heavy naphtha fraction, boiling at a lower range than the kerosine, may be taken from near the top

of the tower for reforming to a higher octane number. The heavy residuum from the tower bottom is pumped to a separate coil in the cracker, where it is heated for viscosity-breaking, to produce a heavier gas oil product for further cracking, a small yield of gasoline, and heavy fuel oil bottoms.

In the unit referred to here, the heavy residuum is heated at 880°F. and 220-lb. pressure along with a heavy recycle stock to yield heavy cracking stock and heavy fuel oil, which is not cracked further because of its very heavy gravity and the amount of extremely heavy material present, which cokes-up still tubes very rapidly. A second coil cracks the heavier gas oil and recycle stock at 960°F. and 500-lb. pressure. The third coil is used either for cracking a light gas oil and recycle stock on a once-through basis, at 960°F. and 750 lb., or for reforming a heavy naphtha (lighter than kerosine), at 975-1000°F. and 750 lb. The light gas oil was 16 percent of the crude, the 55-octane number virgin gasoline was 27 percent, and 57 percent reduced crude was fractionated to yield heavy gas oil, with 25 percent heavy fuel oil as the total fuel oil yield from the unit. The final yields were 68 percent of stabilized gasoline of 66-octane number, 25 percent fuel oil, and 6-7 percent gas loss.

In a similar, four-coil operation on Michigan crude, 7.3 percent of a 221°F. endpoint, 64-octane number, straight-run gasoline was removed from the crude by heat exchange and flashing in the crude tower; the reforming coil operated on heavy naphtha of 453°F. endpoint, at 750 lb. and 975°F.; the light oil coil operated at 600 lb. and 995°F.; the heavy oil heater at 400 lb. and 925°F., and the viscosity-breaker was run at 235 lb. and 880°F. To reduce the fuel oil to the low gravity desired the fuel oil flash tower, into which the heavy residuum is flashed after heating, was maintained at 1-lb. gauge pressure by a steam ejector.

Yields from this refractory crude by this operation were 64 percent of total stabilized gasoline of 396°F. endpoint and 63-octane number, 25 percent of 9.6-gravity fuel oil, and about 11 percent gas loss.

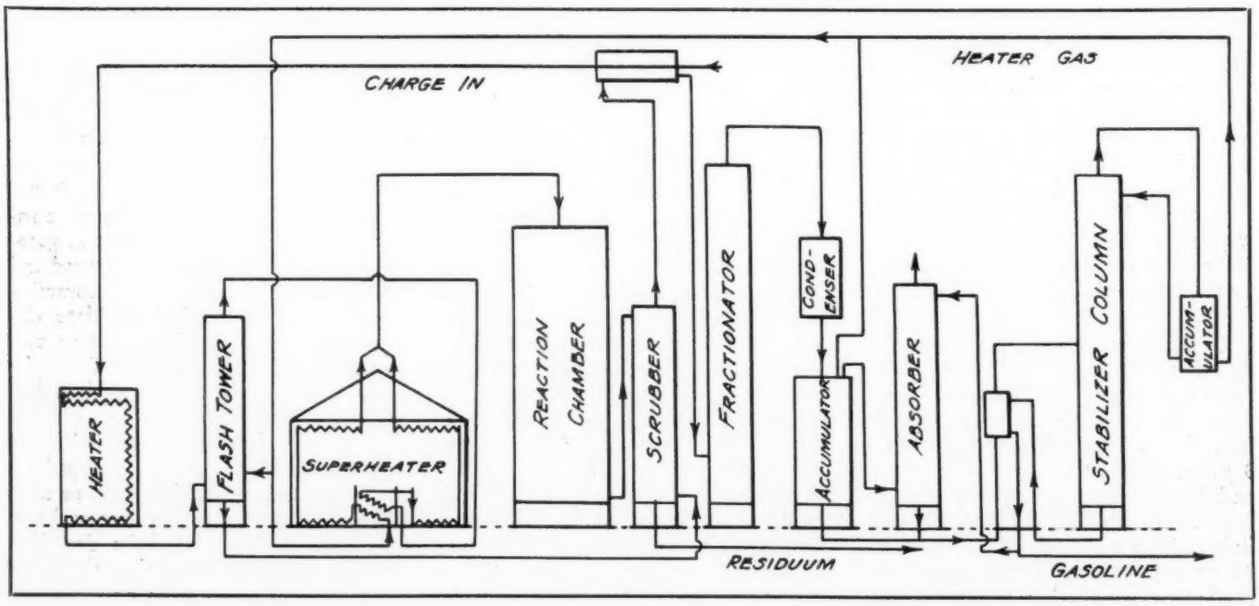
Another type of operation is the so-called coking method. By this process a series of heavy reaction chambers are connected to the charge transfer line, in parallel, and the heated charge is led into each of these chambers, in turn, at temperatures and pressures comparable to those mentioned above, maintained therein at essentially those temperatures for varying lengths of time, the cracking reaction continuing and depositing coke in the chamber. The "soaked" charge minus the deposited coke is then flashed in a separate chamber where the pressure is reduced to 30 lb. or lower. Much of the charge is vaporized in this chamber and passes overhead to the fractionator while the heavy residuum is withdrawn and reheated, continuing this cycle until all the charge is either cracked to gasoline or deposited as coke. Thus only three products are made in this system, gasoline, coke, and gas. The gas may be used as still fuel, after the 3- and 4-carbon olefins are extracted and polymerized into high octane number gasoline, as will be discussed in a later article.

Yields from this type of operation will be as high as 68-72 percent of 70-74-octane number gasoline, not including the virgin gasoline removed in the crude still, the percentage of which will vary with the crude—averaging about 20 percent for Mid-Continent crudes—10 percent or more gas loss, and the remainder, 20 percent more or less, coke. Comparable yields when running to a good grade of 8-10 gravity fuel oil will be 50-55 percent of the reduced crude to cracked gasoline, 25-30 percent fuel oil, 5-10 percent gas, and a negligible amount of coke.

Innumerable variations of these operating conditions and yields are employed in the complicated cracking units now in use, too many to outline here even briefly. These few examples serve to indicate the typical conditions employed in a so-called mixed-phase cracking unit, a type of operation that is responsible for nearly half the quantity of gasoline now produced in America.

The cost of operating cracking units varies so widely that only very general terms may be given. In one instance the overall operating cost is estimated at 40 cents to $1.00 per bbl. (*National Petroleum News*, May 4, 1938, page R-206), of which 22 percent is labor, 36 percent fuel, 20 percent maintenance and cleaning, and 22

Fig. 2. Simplified flow chart of vapor-phase cracking unit



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L 3901

FIELD: Horse Shoe Bayou State Land
TYPE OF JOB: Casing cement job
DEPTH OF WELL: Casing set at 11,631 ft.
MAX. TEMP.: 2500 F.
SLURRY WEIGHT: 16 lb. per gal.
CEMENT USED: 'Starcor', 1500 sacks
MIXING TIME: 32 min.
PUMPING-DOWN TIME: 55 min.
MAX. PUMP. PRESSURE: 2500 lb.
REMARKS: Note ease with which 16-lb. 'Starcor' slurry was pumped into position. Well - 11,631 ft. deep. Temperature plenty hot — 2500 F.

S 1417

FIELD: Lake Pelto, La.
TYPE OF JOB: Casing
DEPTH OF WELL: 5,500 ft.
MAX. TEMP.: 150° F.
SLURRY WEIGHT: 16 lb. per gal.
CEMENT USED: 'Starcor', 400 sacks
MIXING TIME: 18 min.
PUMPING-DOWN TIME: 27 min.
MAX. PUMP. PRESSURE: 1800 lb..
REMARKS: Formation in this field so soft that holes are almost always crooked. Another good 'Starcor' job, under very difficult conditions.

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percent utilities—steam, power, water, and chemicals. Other estimates, based on different types of operation, show a cost of 26 cents per bbl. actual running costs, when separate units are used for the different steps. A combination unit such as has been described will cost about 20 cents per bbl. by this system of cost accounting. Eliminating the viscosity-breaking reduces this cost to about 17.5 cents per bbl. (*National Petroleum News*, Sept. 7, 1938, page R-415). To include the cost of paying out the unit, overhead expenses, etc., will increase these figures somewhat but exact data can hardly be given that will not be misleading. Return on investment increases with increased throughput capacities; this rate eventually runs into the "Law of Diminishing Returns," at which maximum capacity, however, exact figures are not available.

B. Vapor-Phase Cracking

Vapor-phase cracking methods, wherein the charge stock is vaporized and then brought to cracking temperatures usually at atmospheric or low pressures, are employed in a number of commercial units today and are desirable particularly where special stocks are available. Where the economics of a refiner's position is "right," this process of cracking can be utilized to good advantage on virtually any type of stock that can be vaporized satisfactorily. The charge stock is vaporized by heating in a simple pipestill and flashing in a chamber to eliminate the heaviest fractions. The vapors are then introduced into any practicable heater such as a pipestill, and may be later commingled with a gaseous heating medium such as still or natural gases, flue gases or other vapor material that has been previously heated to temperatures of 1000-1200°F. or any temperature that experience has shown to be adequate to complete the cracking reaction.

As an example of vapor-phase operation, the design and operation of a unit now cracking Pennsylvania gas oil will be outlined. This gas oil is a special stock in that it is the only portion of that crude—except heavy naphtha for reforming—that is cracked, and therefore creates a situation where the combination type of unit is not necessary. This unit consists of a vaporizing still to which the gas oil is charged at 375°F.; a flash chamber where it is vaporized after being heated to about 830°F.; a superheater furnace containing two pipe coils, in one of which the vapors are heated to 960°F. In the other superheater coil still gas taken from the gasoline stabilizer-stripped overhead is heated to about 1200°F.; the heated charge vapors and this superheated gas are mixed by entering a common line just outside the furnace, then pass into the scrubber at 950°F., where it is scrubbed by fractionating tower bottoms. Vapors then pass from here to the tower, from which cracked distillate is taken overhead at a 380°F. vapor temperature, and the tower bottoms, recycle stock, is held at 540°F. and drawn off continuously to be added to the fresh charge in a 2 to 1 recycle-to-fresh-oil ratio to be returned to the vaporizing furnace. Condensed gasoline is received into an accumulator from which it is drawn for stabilization, and from which also a compressor draws gas, compresses and cools it to recover liquid pentanes and sends part of the stripped gas, along with stabilized tops, to the recycle gas heater, another part to the "flash gas" heater, from which the gas is discharged into the flash drum to aid in vaporizing the incoming heated charge stock.

Pressures in this unit are nominal as compared with mixed-phase methods discussed earlier. The vaporizer furnace operates at a temperature of about 1300°F., the cycle gas furnace at 1450°F., the superheater at 1250°F., and the reboiler oil, used in a heat exchange type of reboiler to strip the stabilizer tower bottoms (stabilized gasoline), is used at 580°F. The flash drum operates at 150 lb. gauge, the scrubber at 120 lb., the recycle oil pump discharges at 375 lb., whereas the fractionating tower is under 95-lb. pressure.

The yield of gasoline from this operation is about 67 percent of the charge stock, with 17-20 percent gas loss and 11-13 percent heavy fuel of 3.0-5.0 gravity. The octane number of the cracked gasoline is about 75; however, when 2300 bbl. of cracked gasoline is blended with 2800 bbl. of 53-55-octane number virgin gasoline, the blend shows a 70 A.S.T.M. octane number. From these data the blending octane number value of the cracked product is calculated to be approximately 90 to 95.

This type of unit has also been operated on heavy naphtha as a reforming unit with interesting results. Removing a 250°F. endpoint virgin gasoline of 67-octane number from the crude first, a heavy naphtha cut is taken, amounting to about 20 percent of the crude, having endpoint of 420-430°F., and octane number of about 35 A.S.T.M. Operating on this heavy naphtha in the same general manner as described for gas-oil cracking, this unit has processed as much as 1000 bbl. to give 80-82 percent yield of 410°F. endpoint and a blending octane number of 90 or higher, the blend of virgin and cracked gasoline having 70-72-octane number. Pressures and temperatures used are of the order of those employed for cracking gas oil, such as 95 lb. on the stabilizer absorber and 125 lb. on the reaction chamber or scrubber.

This unit may be taken as indicative of principles of operation of vapor-phase cracking. This principle has been so incorporated to one degree or another into mixed-phase operation that the two types of process cannot always be differentiated.

Recently much attention has been given to other variations of cracking operations. In the vapor-phase (T.V.P.) process just described data are available to show that several percent increase in yield is obtained by superheating the vapors with still gases, as compared with results when inert gases such as flue gas are used. Presumably this is the result of polymerization of the light gases with the heavier vapors or their cracked products during the intimate contact time in the scrubber.

More recently much curiosity has been aroused by verbal rumors of Polyform cracking methods, about which nothing of importance has been made public. This process is being widely applied in commercial practice, but because of an involved patent situation developing between different companies, technologists who are informed on the subject are loath to discuss the process in any manner.

In one semi-commercial-sized experimental plant the method of combining butanes and propanes from refinery and natural gases with gas oil charge stock has been studied with, it is understood, some interesting results. Whatever the reactions that take place, that of polymerization between lighter and heavier molecules, as well as polymerization of light-to-light molecules, doubtless occurs; in addition hydrogenation effects may very probably be present. A similar operation has been used, we are told, in two or three commercial-sized units, by two or more refining companies.

The literature and technology of thermal cracking is so voluminous that no more than a glimpse of the "high spots" of this tremendously important and fascinating field can be given in a few hundred words. From the few examples and facts given above the young engineer can obtain a general idea of the ramifications of the field, which is still doubtless only in its infancy.

Editor's Note: The next article will take up the more recently developed and more fascinating field of catalytic cracking.

IDEAL

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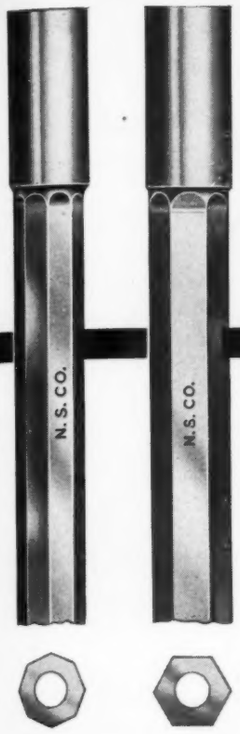
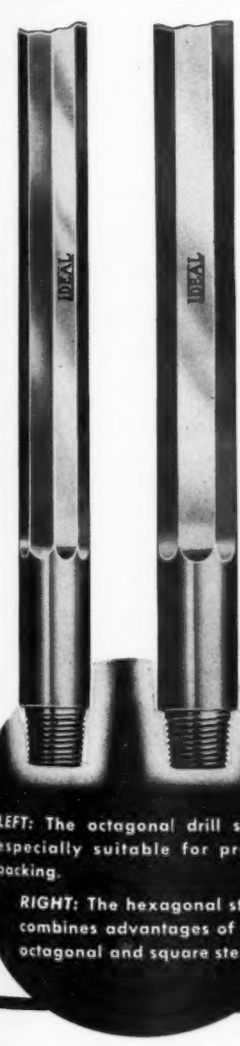
DRILL COLLARS





LEFT: The octagonal drill stem is especially suitable for pressure packing.

RIGHT: The hexagonal stem combines advantages of the octagonal and square stems.

Drilling stresses have no respect for weak sections especially where service is severe. That is why it pays to specify Ideal Alloy Fully Heat Treated Drill Collars.

Forged from the highest quality billets, heavy hammers reduce every inch of the steel into a fine grained structure. Extra endurance and toughness are literally hammered-in.

After the forging operation, three separate full-length heat treatments are given to insure hardness, toughness and strength in the best combination for exacting service.

Specially built machines that bore simultaneously from both ends insure a true center bore. Circulation holes are straight, smooth, and accurately centered. The resulting uniform wall thickness contributes to greater strength and balance, and smoother rotation at higher speeds.

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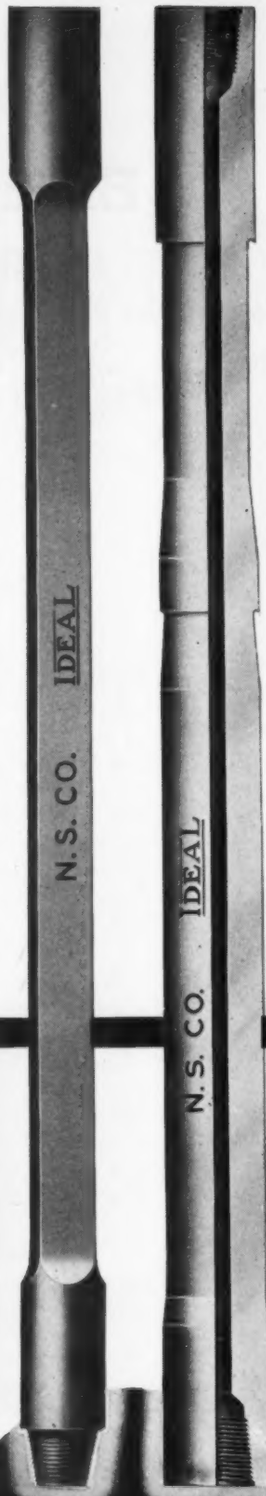
DRILL STEMS

Ideal Upset Drill Stems are made in square, hexagonal and octagonal types. They are forged in one piece from selected steel billets and normalized to equalize and remove forging strains. The ends are further heat treated to give the best combination of hardness, toughness and strength. True center bore circulation holes are insured by the same method of boring as used on Ideal Drill Collars.



LEFT: The square stem has the best driving characteristics.

RIGHT: Ideal Drill Collars are made in all regular sizes and specifications.

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Efficiency and Load Tests On Well-Pumping Unit

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Series of tests on a conventional type pumping unit were made to determine the efficiency and load with tail bearing in three different positions

By BAYO HOPPER

Mechanical Engineer, Lufkin Foundry and Machine Company

BAYO HOPPER

received his bachelor's degree in mechanical engineering from the University of Texas in 1933—Before entering school he worked for three years in the shops of the Lufkin Foundry and Machine Company, Lufkin, Texas, and while at the university served as instructor in the mechanical engineering shop—He has been with the Lufkin Foundry and Machine Company since graduation —Has served in various capacities in the engineering department and has done a considerable amount of field test work on pumping wells.

THE OBJECT of these tests was to determine the relative merits of pumping unit designs: (1) with the tail bearing below the walking beam on a centerline with the center-bearing, (2) with the tail bearing above the beam, and (3) with the tail bearing above the beam and the gear box set back from its usual position.

Description of Equipment

These tests were conducted on a recently abandoned well producing only salt water, located on the extreme west edge of the East Texas field. The well was equipped with 2½-in. tubing, 2¼-in. plunger, ¾-in. rods, the pump being at a depth of 3000 ft. The well was capable of maintaining a constant fluid level after a brief period of pumping.

The production was gauged in a standard test tank where 1 in. of fluid depth equals 1 bbl. There was also installed in the 2-in. flow line at the well a regular water meter having 1-in. inlet and outlet.

The pumping unit used was a Lufkin Twin Crank 550-7B herringbone geared 11.1 hp. (54,945 in-lb. A.P.I. peak torque) unit mounted on a structural base, having adjustable counterbalance cranks of 42-in. maximum stroke, wire-line hanger, 5 ft. and 5 ft. working center walking beam arranged for the tail bearing to be mounted above or below the beam.

The unit was connected by a V-belt drive to a General Electric induction motor, Model 5 KG 405 AX1, Frame 405, Type KG, Volts 220/440, amp. 59/29.5, 3-phase, 60-cycles, full-load speed 865 r.p.m., 20 hp., continuous 50°C. rise, No. 5 310 892.

Power consumed was measured with a General Electric polyphase watthour meter, Type D-14, 60 cycles, 25 amp., 460/480 volts, No. 18 028 123.

Input power peaks were measured with an Esterline Angus wattmeter, Model AW, serial No. 27799, 5 amp. Current transformers of 10 to 1 ratio were used with the wattmeter.

Polished-rod loads were measured with a Westinghouse polished-rod dy-

Fig. 1. Centerline assembly

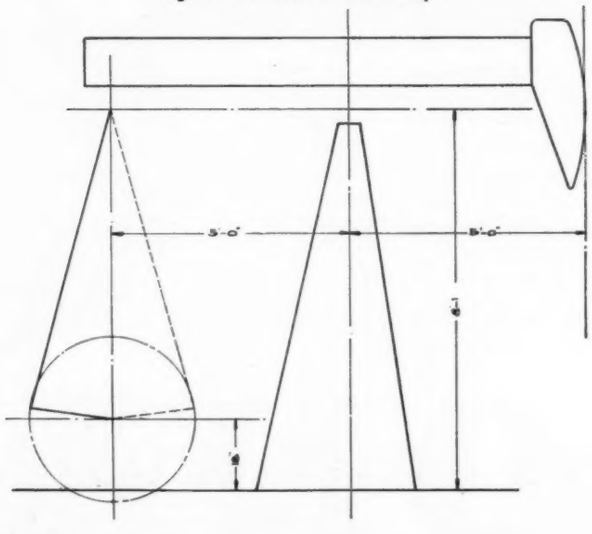

Fig. 2. Bearing above beam

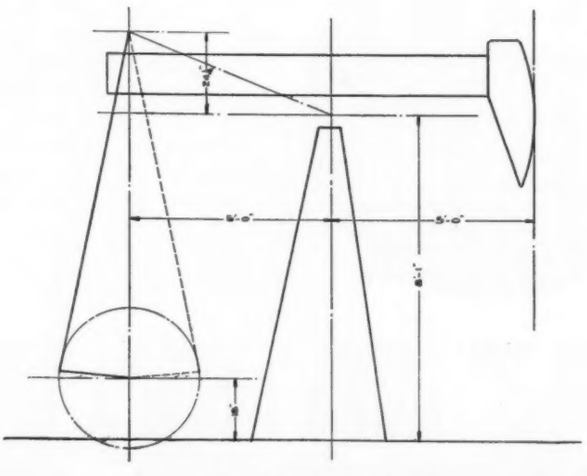

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TABLE I
Results of Tests

Test no.	Unit assembly	S.P.M.	Polished-rod stroke	Duration of test, hr.	Power consumed per 24 hr., kw-hr.	Fluid produced per 24 hr., bbl.	Kw-hr. per bbl. fluid produced	Average hp. input	Average polished-rod hp.	Overall efficiency of unit and motor, %	Peak kw. input			Peak polished-rod load, lb.	Minimum polished-rod loads, lb.	Counterbalance, lb.
											Upstroke	Downstroke	Average			
A	Tail Bearing	22.15	42.75	3.25	191.6	180.9	1.059	10.70	5.596	52.3	19.7	21.35	20.5	6320	1720	4660
D	Above Beam	22.15	43.0	2.5	192.7	182.4	1.056	10.76	5.658	52.6	19.1	19.5	19.3	6110	1080	4170
Average					192.15	181.65	1.0575	10.73	5.627	52.45	19.4	20.425	19.9	6215	1400	4415
B	Set-back	22.15	41.4375	5.75	181.9	168.0	1.083	10.16	5.21	51.3	19.43	19.83	19.63	6130	1340	4360
E	Set-back	22.15	41.6875	3.0	181.6	168.0	1.081	10.14	5.35	52.8	17.39	16.92	17.155	6040	1300	4300
Average					181.75	168.0	1.082	10.15	5.28	52.05	18.41	18.375	18.39	6085	1320	4330
C	Center-line	22.15	42.8125	3.0	196.8	206.0	0.954	10.98	5.87	53.5	19.85	18.25	19.05	6650	1750	4560
F	Center-line	22.15	42.8125	4.5	190.8	203.3	0.939	10.66	5.758	54.0	18.53	17.03	17.78	6250	1500	4610
G	Center-line	22.15	42.8125	4.0	191.1	200.8	0.952	10.67	5.869	55.0	18.57	18.39	18.48	6360	1510	4700
Average					192.8	203.4	0.948	10.77	5.832	54.17	18.98	17.89	18.44	6420	1587	4623

nagraph, style No. 1014851-A, serial No. 18. A 1⅛-in. bronze polished rod was used in order to obtain as large a polished-rod card as possible.

Testing Procedure

Before beginning a record of the test data, the unit was operated each day for a period of 30 minutes to an hour after the counterbalance weights were adjusted as accurately as possible. Upon beginning the test the following readings were taken: Watthour meter and water meter readings were taken simultaneously with the tank gauge, the polished-rod card reading was taken immediately afterward and simultaneously with the counting of the watthour meter disk revolutions. Then a wattmeter chart was obtained.

It has been found that the swing of a wattmeter needle, as it oscillates back and forth to indicate two maximum and two minimum peaks during one pumping stroke, does not reach or indicate the actual peaks on the motor. There is a slight lag in the action of the needle that prevents the natural swing of the needle from going high enough to give a true picture of the power peaks. Assume the needle is going upward to indicate the peak load on the upstroke of the rods: The impulse for the needle to go upward strikes the needle and is gone almost instantaneously; so that due to the slight lag in the needle, the impulse for the needle to go downward strikes the needle and sends it back before it has had time to reach its true peak. The same thing happens, in the opposite direction, to the minimum peaks.

In order to obtain the load peaks, the needle was held over to the right with a pencil far enough for the needle to give only a slight kick, and this point was taken as the peak.

Readings on all the instruments and polished-rod cards were taken at 30-minute intervals whereas the tank was gauged every hour and a half. Tests were continued for 4½ to 6 hours and in each case there was evidence of the well having pumped at a static condition for a period of 2.5 to 5.75 hours, as the hp. input and motor peaks had reached a constant condition.

Only one test was run each day, and the unit assemblies were alternated in the following manner so that a possible change in well condition would not favor or penalize any unit set-up:

Test A. September 29, bearing above beam.

Test being made with bearing under beam

Test with bearing above beam

Here is Pump Liner News!

The inner surface of Harrisburg Seamless Steel Pump Liners can be maintained for any pre-determined depth to a Brinnell hardness of from 600 to 625.

The outer surface can be maintained for any pre-determined depth to a Brinnell hardness of from 200 to 250.

No operation such as metal spraying, alloy insertions, case hardening or other surface additions are resorted to. There is no sharp line of demarcation between the two.

Harrisburg Pump Liners are forged seamless from steel of special alloy composition and uniform in chemical analysis throughout every liner. Every liner is carefully gauged and inspected for precision of diameter and threading. Rockwelled for hardness before shipment. Additional Harrisburg oil field products are Seamless Steel Couplings and Bull Plugs, Drop Forged Flanges. Write

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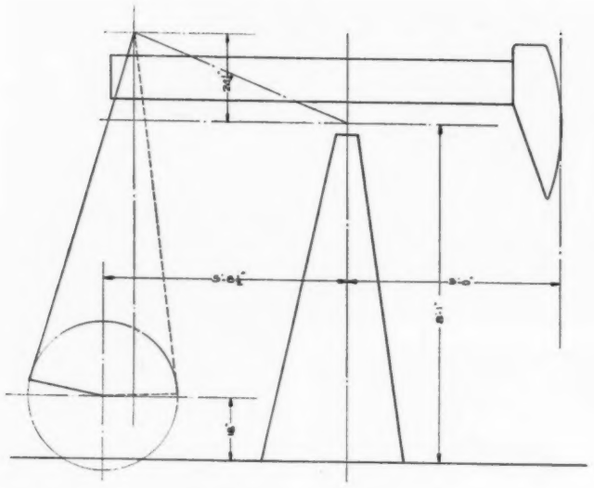

Fig. 3. Unit set-back, bearing above beam

Test B. September 30, bearing above and unit set-back.

Test C. October 3, centerline assembly.

Test D. October 4, bearing above beam.

Test E. October 5, bearing above and unit set-back.

Test F. October 6, centerline assembly.

Test G. October 7, centerline assembly.

The unit was operated only in a counter-clockwise direction, in the 42-in. crank stroke and at 22.15 s.p.m.

Figs. 1, 2, and 3 are line drawings of the three assemblies used.

Results and Conclusions

The results of this test indicate beyond doubt that the centerline type pitman tail bearing is the most desirable. Referring to the table of results (Table 1) and comparing the unit having the tail bearing above the beam (Fig. 2) with the centerline beam unit (Fig. 1), it is found that the centerline beam produced 12 percent more fluid at the same pumping speed and almost exactly the same polished-rod stroke. This fluid was produced at about ⅓ of 1 percent more power per day; so that the cost in kw. per bbl. was 11.6 percent more for the bearing above the beam.

The average hp. input to the motor was approximately the same in both cases, but the centerline type beam produced a better shaped polished-rod card having slightly more area, which gave that assembly 1¾ percent greater overall efficiency. The power peaks for the centerline assembly were less than those for the bearing above the beam by about 7.5 percent. The peak polished-rod loads for the centerline type beam were higher by 3⅓ percent because more fluid was lifted; however, the minimum loads were also higher by about 13 percent. Almost 4½ percent more counterbalance was required by the centerline set-up because of the additional fluid pumped.

Comparing the centerline type pitman tail bearing assembly (Fig. 1) with the tail bearing above the beam and the unit set-back 8½ in. (Fig. 3), it was found that the centerline bearing produced 21 percent more fluid at about 3 percent longer polished-rod stroke and the same speed. This fluid was produced at 6 percent more power per day; so that the fluid was produced with the bearing above the beam at more than 14 percent greater cost in kw. per bbl.

The average hp. input to the motor and the polished-rod hp. were both slightly greater for the centerline beam, but the net result was that the centerline beam was better than 2 per-

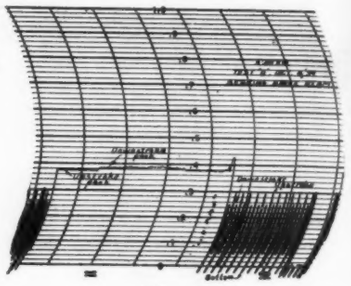

Fig. 4

cent more efficient. The power peaks to the motor were approximately the same, the actual difference being less than 0.03 of 1 percent. The centerline beam showed an increase of 5½ percent in peak polished-rod loads, but an increase of 20 percent in minimum polished-rod loads. The centerline beam required 6¾ percent more counterbalance due to the greater amount of fluid produced.

It is seen from these results that every point investigated proved definitely to be in favor of the centerline beam except polished-rod peaks and counterbalance. These were higher because of the additional fluid pumped, but they did not increase in proportion to the amount of fluid produced.

Comparing the assembly with the tail bearing above the beam (Fig. 2) to the assembly with the tail bearing above the beam and gear box set-back (Fig. 3), it is found that in the set-back position the unit consumed 5½ percent less power and produced 7½ percent less fluid, which resulted in 2¼ percent more kw-hr. per bbl. The overall efficiency is virtually the same, but the set-back position showed 7½ percent lower peaks to the motor.

The extremely low overall efficiency

Fig. 5. Typical polished-rod cards

Test "A"—Bearing above beam

Test "B"—Unit set-back

Test "F"—Centerline assembly

TYPE 2RS ROLLER KELLY DRIVE BUSHING FOR SQUARE KELLYS

STOP

KELLY-BINDING

New Type 2R Baash-Ross Roller Kelly Drive Bushings END FRICTION— STAND THE GAFF

You can't have sensitive feed control and accurate weight indications unless you first *do away with frictional resistance between the kelly and the drive bushing.* The logical, economical means of preventing the kelly from binding under modern high torque loads is a ROLLER kelly drive bushing — the new Type 2R BAASH-ROSS Roller Kelly Drive Bushing, in fact.

Here are the reasons why Baash-Ross Type 2R Roller Kelly Drive Bushings stop kelly-binding, stand up under hardest use, give long, economical service: The whole assembly is heavily proportioned for great strength; each driving surface of the kelly is contacted by two extra large diameter, individually lubricated rollers, and by no other part of the drive bushing; low-cost replaceable roller bushings and reversible roller pins absorb virtually all of the wear.

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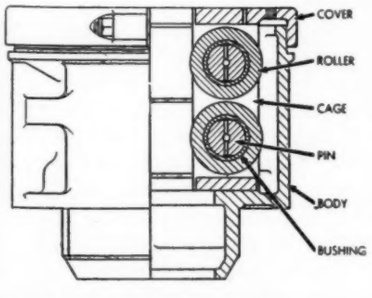

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TYPE 2RH ROLLER KELLY DRIVE BUSHING FOR HEXAGONAL KELLYS

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was due to the fact that the power factor was unusually low. Although the power factor was not definitely determined, it was estimated through a rough check by a power company engineer to be not much better than 50 percent.

In Fig. 4 is shown a sample of the wattmeter chart taken on Test "D", with the bearing above the beam. The upstroke peak appears to be considerably higher than the downstroke peak, which would indicate an under-counterbalanced condition. However, when the needle is pushed with a pencil up to the farthest position at which it will move, it is found that the downstroke peak is actually somewhat higher than the upstroke peak.

The unit was run clockwise for a short time in the set-back position with a resulting increase of about 20 percent in power peaks to the motor.

The reason for the difference in polished-rod strokes on tests A and D and also on tests B and E is because the bracket for holding the tail bearing in position above the beam was only clamped in place, and in changing tail bearing positions it was necessary to drive a tight fitting pin in and out of place. In making this change, the clamped bracket was shifted forward slightly, resulting in a little longer polished-rod stroke on the second round of tests.

The centerline type assembly was penalized in regard to pitman angularity, because in changing to the other two assemblies the pipes were made longer, the other parts of the assembly remaining the same. As a matter of fact, in actual practice in every case where the tail bearing is used above the beam, the samson post is either made shorter or the gear box is set on a sub base and so would make the pitmans shorter than those used in the test. Thus with the bearing above the beam, the pitman angularity was more favorable than will be found on any commercial job. For a more exact comparison, all the tests should have been run with the same length pitmans.

One mistake that is sometimes made when comparing these assemblies analytically is to assume that all the assemblies will produce the same shape polished-rod card. A study of the cards obtained on this test will prove that this assumption is not correct and that a more favorable card is obtained when using the centerline assembly.

In running the tests, every effort was made to read the instruments and record the data as accurately as possible. It has no doubt been noticed that tests A and D, which were on the same unit set-up and which were taken several days apart, show results that are almost identical. The various tests on the other two assemblies also show almost identical results. So that, at least for the pumping conditions investigated, the results obtained and the conclusions made can be depended upon as being close to 100 percent accurate.

Acknowledgments

Grateful acknowledgment is hereby made to Sun Oil Company for its cooperation in making these tests. Appreciation is also expressed to the following for their suggestions and assistance: Charlie Webb, Sun Oil Company; Riley Aucoin, Humble Oil and Refining Company; Joe Ward, Mr. Webb and Mr. Ellis, of Texas Power and Light Company.

Reference

"Efficient Operation of Pumping Rigs," Shutts and Thomas, A.P.I. Proceedings, Division of Production, Midyear, 1931.

Exploitation of Petroleum in Albania Has Been Mostly by Italian Interests

IT WAS ONLY upon the outbreak of the World War that Albania became the "mecca" of intense petroleum research, says a report to the U. S. Department of Interior by Consular Clerk Ivan Lavretsky, Genoa, Italy.

The Societa Italiana delle Miniere di Salenizza was the first to drill test wells in the district of Susica, about six miles from Valona, and the results achieved were highly satisfactory. But despite this technical success the British Government was the first to obtain exploitation rights over an area of 42,000 hectares. In 1925, Italy was granted two concessions in the vicinity of Tirana by the Albanian Government, to which were added three other zones in the same year, forming together a total area of 60,000 hectares. At this time the Standard Oil Company of New York also received a concession of 55,000 hectares and another of 35,000 hectares was granted to the Franco-Albanian Company. Each concession was subject to an exploitation rental of 1.50 francs per half hectare, or approximately 13.75 percent on the petroleum extracted. Very soon all the nations that at first vied with each other for the exploration of these petroleum lands, withdrew from the field, leaving Italy alone to persevere with its own means.

Since 1925 Italian technologists have performed drilling operations from which the Albanian Government in that year alone obtained a rental of 30,000,000 lire. Two years later this figure had increased to 50,000,000 lire. Research operations were thereafter intensified and drilling operations covered an area of 200,000 hectares. Since that time the continual increase in production has proved that the labor employed and capital invested has been fully justified. In fact, from 1928 to 1935, Italy extracted approximately 62,900 bbl. of petroleum of excellent quality suitable for processing in its own refineries. Since 1935 the production has progressively risen to 333,500 bbl. in 1936; 600,000 bbl. in 1937, and 734,000 bbl. in 1938.

The largest quantity was obtained from the Devoli basin, which covers an area of 700,000 hectares, from which it will be possible to recover 80,000,000 bbl. of crude. In these fields work is being carried on by 343 Italians, and 1600 Albanians and the plants erected have been designed to handle a daily output of 6700 bbl. About 100 wells are producing, the oil being taken by the Devoli-Valona pipe line. This line is 46 miles in length and has three pumping stations. The line is constructed of 8-in. pipe and has been laid at a depth of 3.28 ft. so as to obviate any sudden variation in temperature. The three pumping stations have a daily capacity of 6700 bbl. of crude oil at even the lowest temperature. It is possible to eliminate one or two of the stations during the summer months or when the pipe line is not operating at capacity.

At Valona the crude oil is placed in underground storage from which the tank steamers pump the crude oil into their own storage tanks by a modern system of flexible lines.

This petroleum is generally black in color and of high density, but after being submitted to hydrogenation it gives a yield of more than 80 percent of superior-quality gasoline, the specifications of which correspond to those of motor fuels distilled from light oils.

Front View, Battery of 7 CLARK 6-cylinder "Angle" Compressors Totalling 4,200 H.P. in new Gasoline plant, Wasson-Bennett Field

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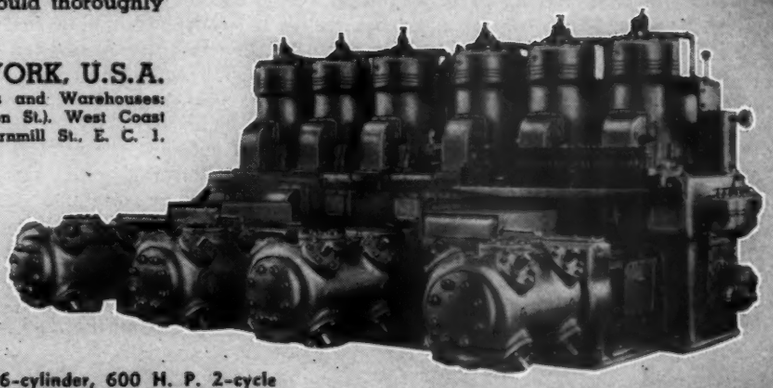

CLARK 6-cylinder, 600 H. P. 2-cycle Right-Angle Compressor

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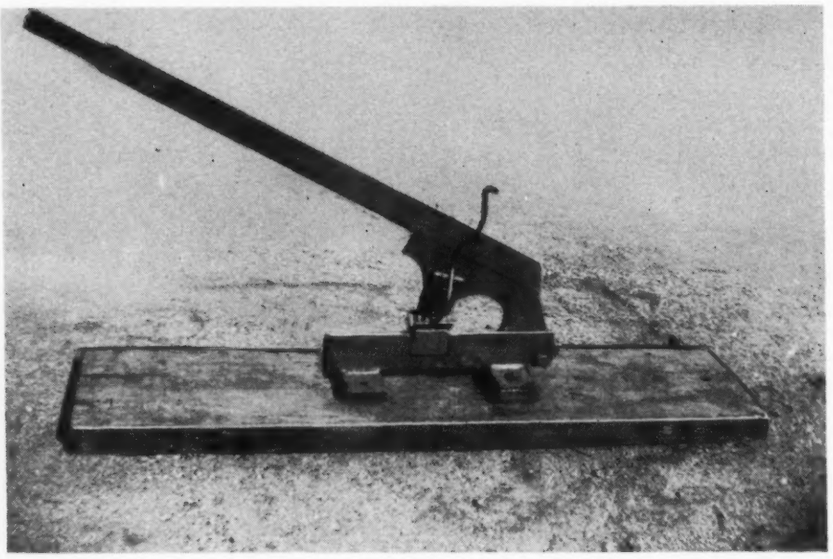


Fig. 1. This machine is used to form coupling bonds. Shown is a bond completely formed except for one of the foot-pieces. First operation consists of forming the two half-circles that go over the coupling. After this the foot-pieces are formed

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Practical Application of Electrolysis Prevention on Pipe Lines and in Compressor Stations

Ground-bed design employs "T" rails—cast-iron welding rod is recommended for attaching coupling bonds to pipe

Part 1

By PAUL F. MARX
Engineer, Northern Natural Gas Company

IN the last few years engineers studying the effects of electrolysis have gained valuable information concerning corrective measures. Many articles have been written and remedies generalized, but still much pertinent information has not been divulged. It is the writer's opinion that, following successful application of proved methods, some of these, under similar circumstances, might be employed to advantage by others in the industry.

In this article will be found special reference to a serious electrolysis condition that exists in compressor stations employing battery ignition systems. Many companies do not realize that this condition exists in their plants but investigation will usually disclose definite evidence of corrosion. The manufacturers of compressors should also be informed of this situation so that future design, by means of simple changes, will eliminate costly repairs.

Cathodic Protection

Electrolysis engineers have many theoretical ideas in connection with types, sizes, and the location of ground beds. In dealing with as many variables as are encountered in such an installation, however, no comprehensive equation can be evolved and simple preliminary tests must be made.

Previously, most companies in their cathodic-unit installations used No. 0000 wire, both for positive and negative leads to the generator and for bonding across couplings. This was, no doubt, brought about because some early installation was made in this manner. When questions were asked as to why this size wire was used no sound reason could be found and recently the tendency has been to decrease the size of the wire. Actual tests show that No. 0 wire is ample in size both for the generator lead wires and the coupling bond wires. Under the most adverse conditions the actual pipe-to-ground potential, when using No. 0 wire, would be from 0.02 volts to 0.05 volts less than with the same amount of No. 0000 wire.

In a shunt-wound generator, as in some windmills and gas-driven units,

(Continued on Page 51)

PAUL F. MARX

received his education at the Western Military Academy, Alton, Illinois, and the Colorado School of Mines—Since 1921 he has followed experimental and engineering lines and has been affiliated with the following companies: American Metals Company, Ltd., experimental floatation; Standard Oil Company of Indiana, combustion engineer; White Eagle Oil and Refining Company, development department; Skelly Oil Company, propane and butane experimental work; engineer for eight years with the Natural Gas Pipeline Company of America—Since his association a year ago with the Northern Natural Gas Company he has dealt principally with problems in cathodic protection, electrolysis mitigation, and corrosion.

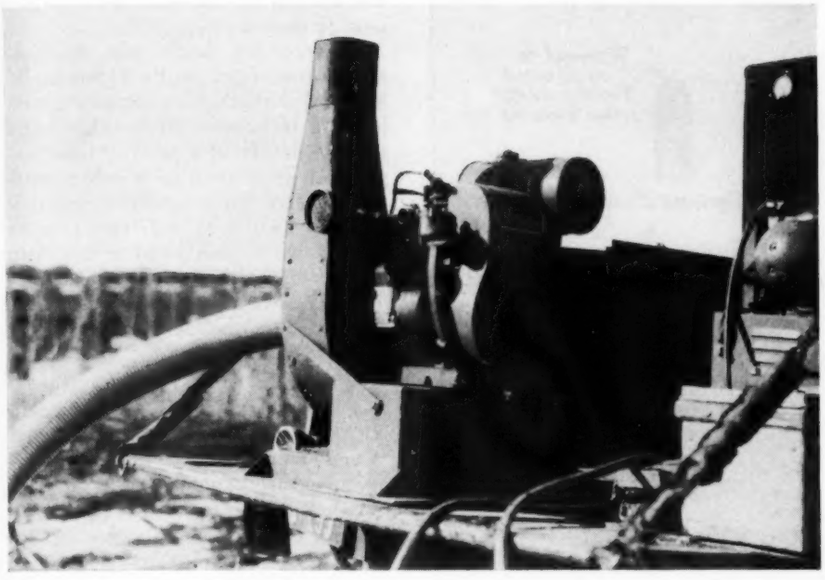


Fig. 2. Engine-driven fan for removing fumes from bell-hole

(Continued from Page 48)

an increase in external resistance increases the shunt field, and in turn increases the voltage and decreases the amperage at a constant speed. Two things transpire: The increased voltage tends to "push" the current farther and the decreased amperage lessens the current density, the net result having a compensating effect. Under the adverse conditions mentioned, however, the use of a No. 0000 wire, at its high price difference over the No. 0 wire, certainly is not warranted. There is a rubber-covered underground cable now available that is especially good and easy to handle when used as lead wires from the generator.

Many tests have been conducted on methods of bonding and bonding efficiency, together with various types of bonds, and the following has been found to be the most satisfactory at the present time: Bonds are all formed using an 18-in. length of No. 0 soft-drawn copper wire. The forming is done by a simple homemade bond-bending machine. A picture of this machine is included (Fig. 1) so that one of similar design may be easily constructed. The machine is inexpensive and will form a complete bond in two operations; whereas, if the bond were to be formed in one operation, the machine would be more complex due to the copper becoming extremely hard during the stretching operation.

The bond is now ready for installation and may be welded to the pipe by using an electric arc machine employing reverse polarity, a potential of 23 volts, and a current of 80 amp. A $\frac{1}{8}$-in. cast-iron electrode is used and the weld around each base of the bond should be made in one "pass". The bond should also be "spotted" to the center ring of the coupling. When this method is used the overall resistance of the bond from pipe to pipe will be approximately 0.002 ohm.

The use of the cast-iron rod not only eliminates approximately two-thirds of the fumes but also "works" the pipe metal and the copper of the bond together; whereas, when a bronze rod is used, the bond is similar to little dowel pins formed by the bronze after the pores of the steel in the pipe have been opened. The remaining fumes may be eliminated when using the cast-iron rod by a small suction fan, driven by a small air-cooled gasoline motor, to which is attached a flexible tube having a funneled end that may be set in

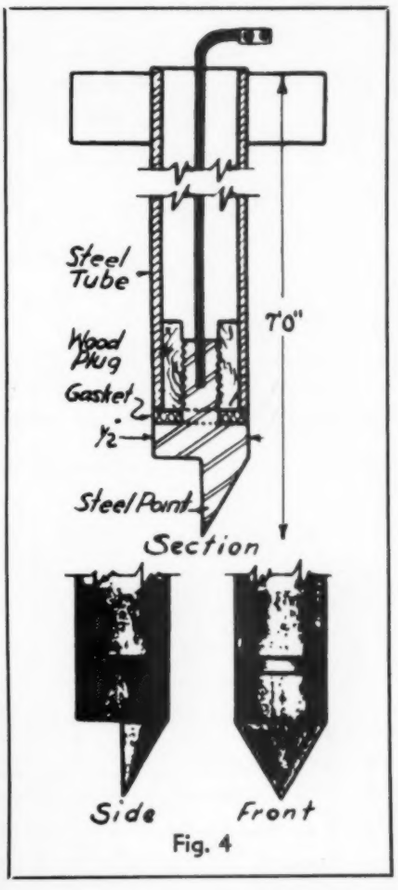


Fig. 4

Fig. 3. Welding and test generator is mounted on wheels for easy portability

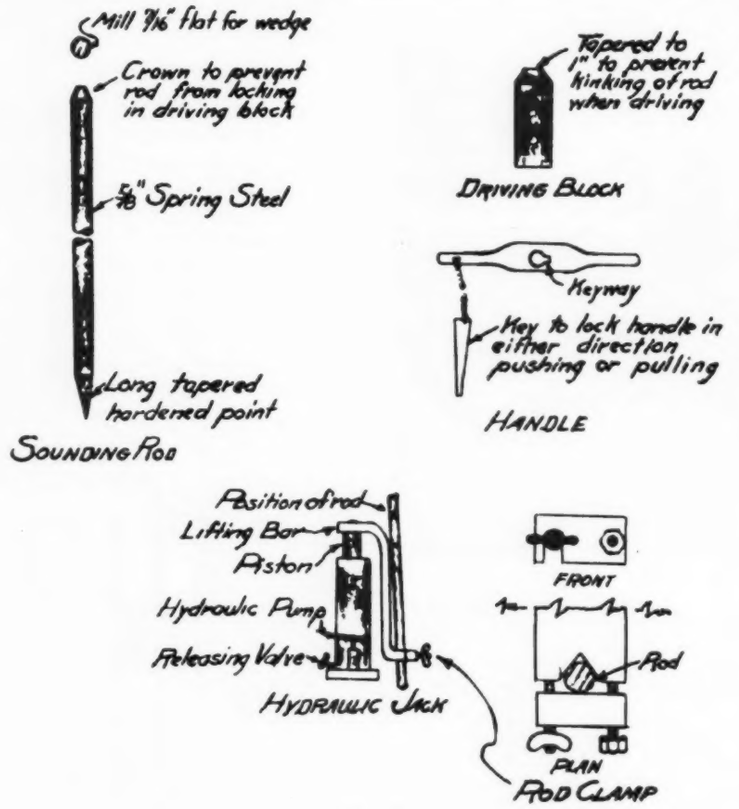


Fig. 5

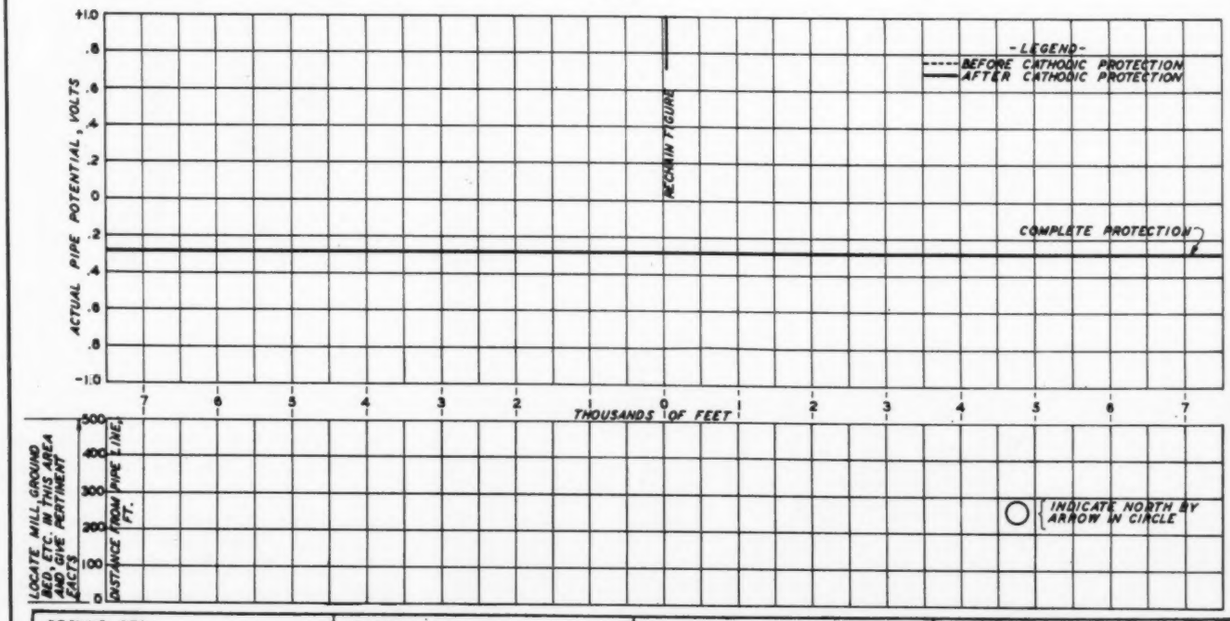
the bottom of the bell hole. Such a unit is shown in Fig. 2.

In very dry sandy soils, approximately 6000 ft. of poorly-coated 24-in. line and a parallel well-coated 24-in. line can be bonded. In similar-type soils, 10,000 ft. of a poorly-coated single line, or in areas in which there is a subsurface water condition, approximately 16,000 ft. of line can be bonded. After this bonding has been completed, it is necessary to make preliminary tests to determine whether or not additional bonding can be made, and also to determine the ground-bed location.

A unit similar to that shown in Fig. 3, composed of a 150-amp. shunt-wound arc-welder, belt-driven by a 16-hp. air-cooled engine, can be used for testing and bond welding. The fan and welding units, together with the panel board controls, and a reel containing 700 ft. of lead wire are all mounted on wheels as illustrated, so that the complete unit may be loaded on a light truck and transported. A million-ohm per volt meter, copper-sulphate ground electrode, and a pipe electrode (as shown in Fig. 4) are used to obtain the pipe-to-ground potentials.

It may be mentioned here that in some type soils where it is extremely difficult to put the electrode in the ground, a sounding rod may be driven-

Fig. 6



GROUND BED: SALT USED _____ LB. WATER USED _____ GAL. CIRCUIT RESISTANCE: INITIAL _____ OHMS; DATE _____ FINAL _____ OHMS; DATE _____	GENERATING UNIT: TYPE _____ RATING: _____ VOLTS _____ AMPS. TESTING: _____ VOLTS _____ AMPS. BOND WIRE: COUPLING: LENGTH OF COUPLING _____ IN. KIND _____ SIZE _____	PIPE TO GROUND BED: LENGTH _____ FT. SIZE _____ PIPE DATA: KIND _____ SIZE _____ WT. _____ LB. PER FT. WALL THICKNESS _____ IN.	LOCATION _____ MILE MARKER _____ TESTED BY _____ CORROSION DATA SHEET NO. _____

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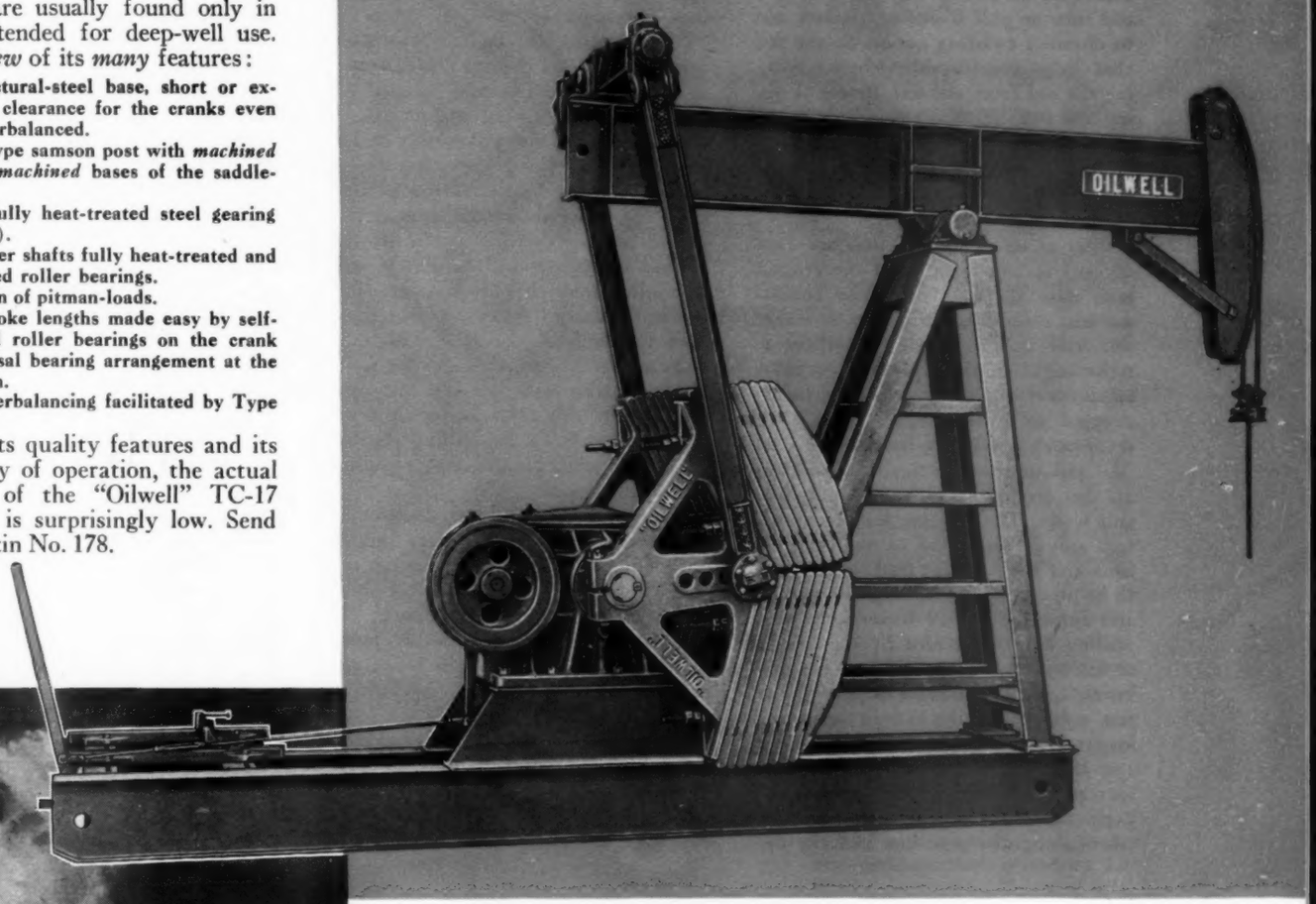

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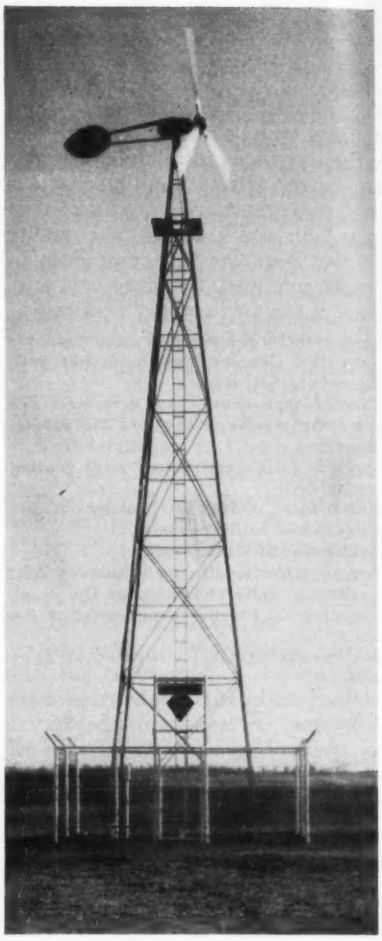
in first, to make a hole in which the electrode may be placed. This sounding rod may be driven in the ground with a sledge by placing the driving block directly on top of the sounding rod. (See Fig. 5.) If it is not possible to pull the rod by hand, the hydraulic jack arrangement shown may be used to extricate the rod. A handle of the type indicated should be used to push the rod into or pull it out of the soil and to obtain a twisting action on the rod that helps considerably when removing the rod from the soil. Before sledging the rod into the ground this handle should be removed. When it is not removed, it may increase the severity of the vibrations, thereby causing crystallization of the rod.

Five or six promising sites are now selected for the location of the ground bed: near the center of the bonded section; several hundred feet to either side, and also at varying distances at right angles to the pipe line. At these locations 8-in. holes are either hand-augered or drilled by well-drilling equipment and a half-length of a steel "T" rail inserted vertically. The holes are then backfilled with dirt, rock-salt, and water. The positive lead from the test unit is connected to one rail at a time and the negative lead, to the pipe to be protected. By reading the voltage and amperage on the meters, the first reading may be divided by the second to determine which location has the lowest circuit resistance at a constant test voltage. As the circuit resistance lowers, the amperage becomes greater and the current density on the pipe increases, affording more protection. Pipe-to-ground potentials are then taken along the pipe line and the determinations made will indicate which location is the best to protect the entire length of line bonded. A curve of these actual pipe potentials can be plotted on a form such as shown in Fig. 6 to obtain a visual picture of what is transpiring along the line.

After the proper location is found, the ground bed may be installed. Using approximately 15 vertical rails at spacings varying from 16½ to 25 ft., a "V" is formed, the legs of which are approximately 16 degrees from the axis of the pipe line. The rails are tied together by welding horizontal rails to the top of the vertical rails and the positive cable from the generator is connected to the apex of the ground bed. The top rails of the ground bed should be two to three ft. below the surface of the ground so that it will not interfere with plowing, etc. The reason for using "T" rails is that these have the surface area of a 6-in. pipe and considerably more weight per foot. Approximately two and one-half tons of rock salt and 2000 to 3000 gal. of water are added in backfilling the augered holes when constructing a ground bed of this type.

After the completion of the ground bed further tests may be made and, if it is found that the overall circuit resistance is much greater than 0.3 ohm, additional rails may be necessary; or, if it is found that considerably more than complete protection is being received on the pipe line, additional bonding can be made.

A gas- or wind-driven generator having a capacity of 2000 watts is used to obtain the maximum protection. A shunt-wound generator, of the type used in one of the windmills on the market, cannot reverse polarity, and increasing resistance, as in drying of soils, automatically increases voltage output, which is advantageous.



Wind-driven generator supplying energy for cathodic protection

Fig. 7

CATHODIC PROTECTION DATA

Date _____ Mile Marker _____ Pipe Line Mile Numbers _____ Pipe Line Name _____

State _____ County _____ Sec. _____ (Twp)(Mlk) _____ (Rge)(Sur) _____ Twp; Plat Sh. No. _____

PIPE DATA: Kind _____ Size _____ Weight _____ #/Ft. Wall Thickness _____ In. Length of line bonded _____ Ft. Unbonded ○

•Wrapping ○ •Coating ○

GROUND BED

Location _____

RESISTANCE DATA

Type of Soil	Depth In Ft.	Ohms/cm³	Station No.

COPPER SULPHATE ELECTRODE

Zero Soil Pot. Volts	Pipe Soil Pot. Volts	Act. Pipe Pot. Volts	As found Ohms/cm³ At Pipe Depth

SOIL

GROUND BED:
Rock Salt Used _____ #
Water Added _____ Gal.

CIRCUIT RESISTANCE:
Initial _____ Ohms, Date _____
Final _____ Ohms, Date _____

GENERATING UNIT:
Type _____
Rating: Volts _____ Amperes _____
Testing: Volts _____ Amperes _____

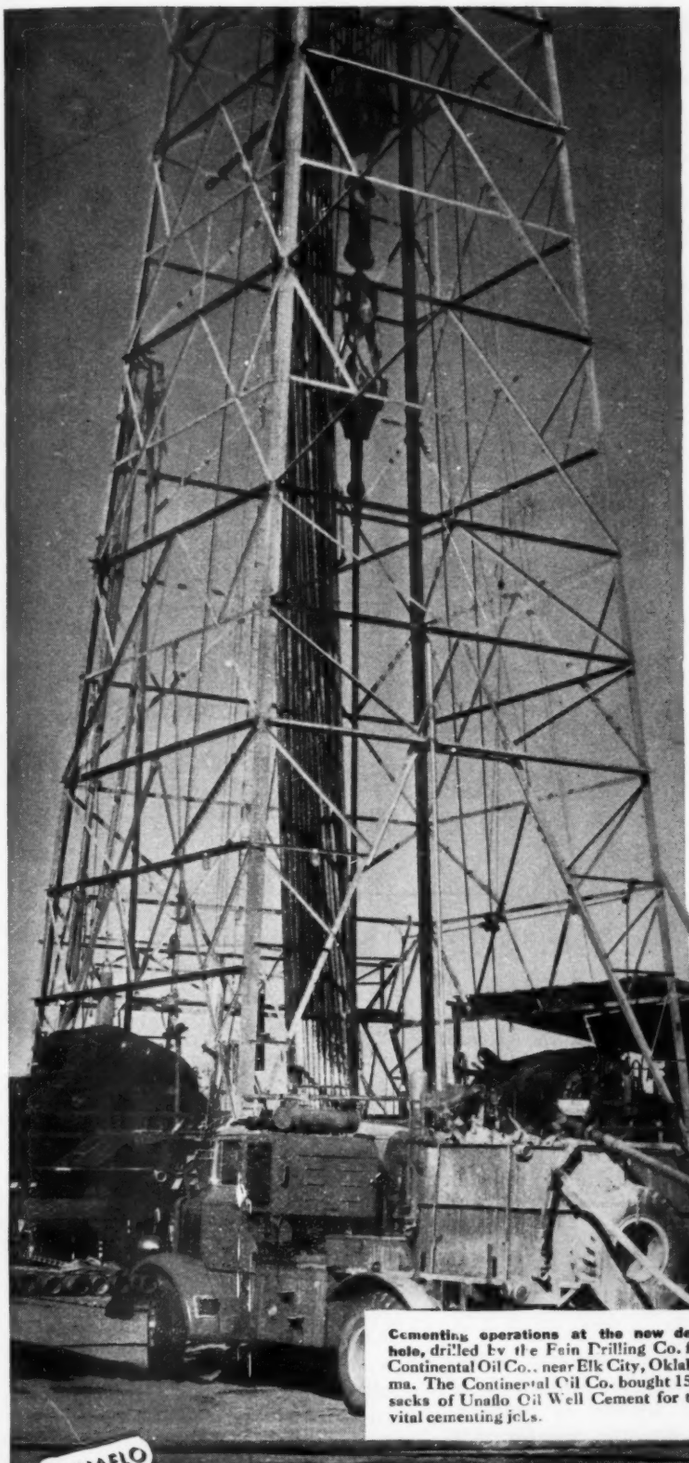
BOND WIRE:
•Coupling:
Length/coupling _____ In
Kind: _____ Size _____
Pipe To Ground Bed:
Length in ft _____ Size _____

NOTES

Effective Resistivity (ρ) _____ Ohms/Cm³
Type Ground Bed: Hor. ○ Vert. ○
Material for Anode _____
Weight _____ #/Ft.
Sectional Circumference _____ In.
Equiv. Pipe Diam. _____ In.
Approx. Resis. of 1 Anode _____ Ohms.

Tested by: _____
Corrosion Data Sheet No. _____

NEWEST DEEP WELL USED UNAFLO



Cementing operations at the new deep hole, drilled by the Fain Drilling Co. for Continental Oil Co., near Elk City, Oklahoma. The Continental Oil Co. bought 1500 sacks of Unaflo Oil Well Cement for the vital cementing jobs.

Well reaches 14,582 ft. following successful cementing operations with Unaflo Oil-Well Cement

THE Fain Drilling Co. used 1500 sacks of Unaflo —the easy-flowing, hard-setting cement with a retarded set—to protect this hole for the Continental Oil Company during extremely deep cementing operations.

At 14,040 ft., trouble developed in this deep test hole. A tough fishing job finally brought up all the pipe except a bit and reamer. In order to carry the hole around the bit, the Fain Drilling Co. ran in a whipstock and cemented it with Unaflo Oil Well Cement. A liner was then successfully cemented in place at that great depth—and high temperature —again with Unaflo! And drilling proceeded to the greatest depth in the Mid-Continent Field today.

Unaflo Oil Well Cement has helped to bring in many a well in the mid-continent field. It mixes and places easily with 35% water... stays pumpable for over 4 hours at 180°... and then hardens thoroughly with high density. It also sets satisfactorily in sulphate water and is not affected by salt water contamination. Use it to protect your next drilling operations.

• Write for "Oil Well Cementing Guide," a new booklet on using Unaflo under mid-continent conditions. Address nearest office. Universal Atlas Cement Co. (United States Steel Corp. Subsidiary), Amicable Bldg., Waco, Texas; Tulsa, Oklahoma City, Kansas City.

PE-U-10

Universal Atlas
CEMENTS

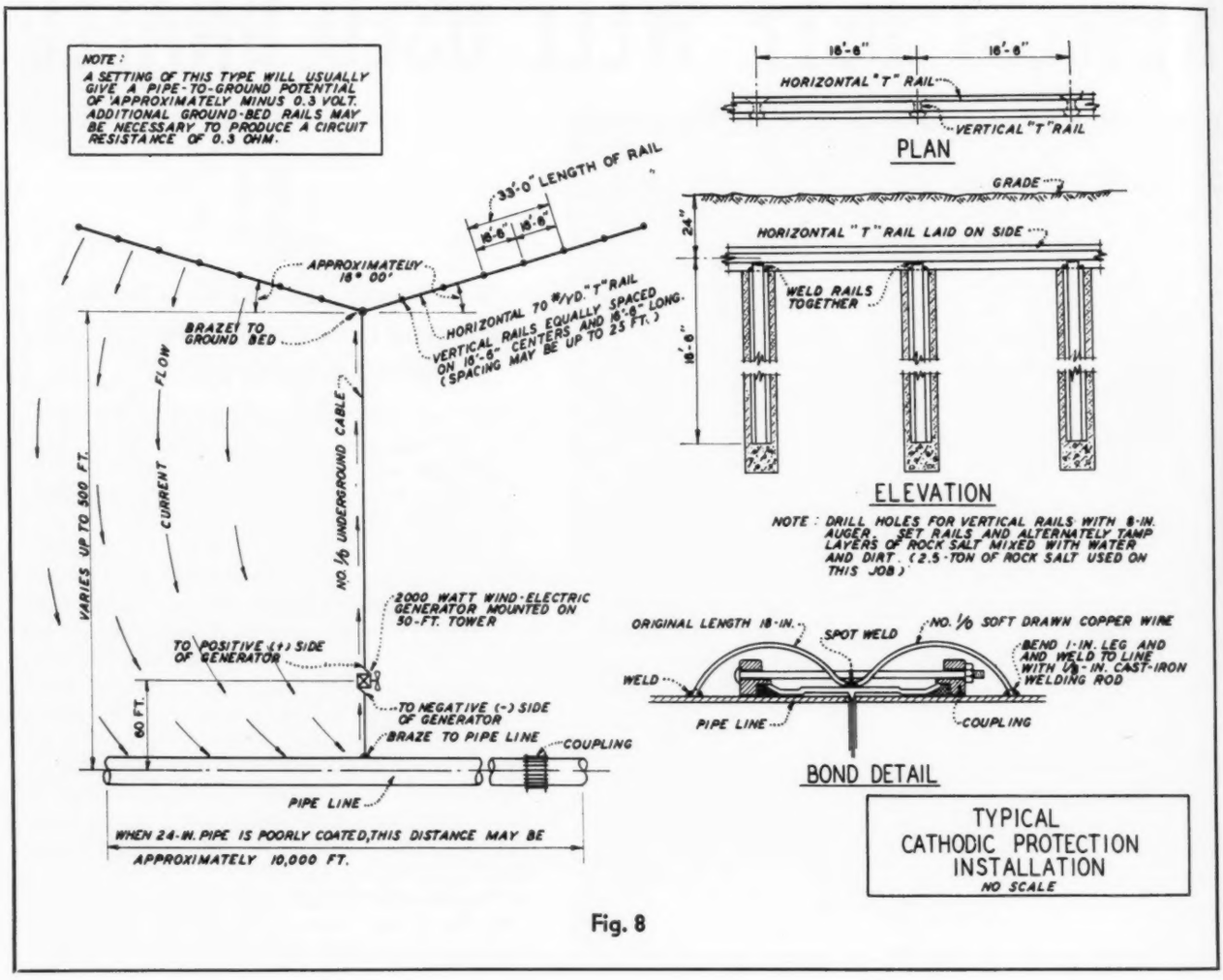

NOTE:
A SETTING OF THIS TYPE WILL USUALLY GIVE A PIPE-TO-GROUND POTENTIAL OF APPROXIMATELY MINUS 0.3 VOLT. ADDITIONAL GROUND-BED RAILS MAY BE NECESSARY TO PRODUCE A CIRCUIT RESISTANCE OF 0.3 OHM.
33'-0" LENGTH OF RAIL
16'-6"
16'-6"
APPROXIMATELY 18° 00'
HORIZONTAL TO #/YD. "T" RAIL VERTICAL RAILS EQUALLY SPACED ON 16'-6" CENTERS AND 16'-6" LONG. (SPACING MAY BE UP TO 25 FT.)
BRAZED TO GROUND BED
FLOW
CURRENT
VARIES UP TO 500 FT.
NO. 1/0 UNDERGROUND CABLE
2000 WATT WIND-ELECTRIC GENERATOR MOUNTED ON 50-FT. TOWER
TO POSITIVE (+) SIDE OF GENERATOR
TO NEGATIVE (-) SIDE OF GENERATOR
60 FT.
BRAZE TO PIPE LINE
COUPLING
PIPE LINE
WHEN 24-IN. PIPE IS POORLY COATED, THIS DISTANCE MAY BE APPROXIMATELY 10,000 FT.
16'-6"
16'-6"
HORIZONTAL "T" RAIL
VERTICAL "T" RAIL
PLAN
GRADE
24"
HORIZONTAL "T" RAIL LAID ON SIDE
WELD RAILS TOGETHER
10'-6"
ELEVATION
NOTE: DRILL HOLES FOR VERTICAL RAILS WITH 8-IN. AUGER. SET RAILS AND ALTERNATELY TAMP LAYERS OF ROCK SALT MIXED WITH WATER AND DIRT. (2.5 TON OF ROCK SALT USED ON THIS JOB)
ORIGINAL LENGTH 18-IN.
SPOT WELD
NO. 1/0 SOFT DRAWN COPPER WIRE
BEND 1-IN. LEG AND AND WELD TO LINE WITH 1/8-IN. CAST-IRON WELDING ROD
WELD
PIPE LINE
COUPLING
BOND DETAIL
TYPICAL CATHODIC PROTECTION INSTALLATION
NO SCALE

Fig. 8

terminals in the meter box. By means of this switch, the necessity for disconnecting the wind-generator leadwires is eliminated. The recording ammeter gives a picture of the entire period a unit operates and the readings from the indicating voltmeter and ammeter may be used to determine any changes in circuit resistance. Line walkers can change the charts once a week.

In exceptionally dry soil a horizontal pipe, the underside of which is slotted, may be laid directly over the ground bed. Then from time to time additional water can be poured into this pipe through a riser, and the ground-bed resistance lowered by seepage of the water.

An accompanying photograph shows a complete wind-driven cathodic unit. Fig. 7 is a form to record cathodic protection data and Fig. 8 is a schematic drawing of an installation.

Editor's Note: Part 2 of this article will be published in an early issue of *The Petroleum Engineer*.

Petroleum Concessions in Island of Sakhalin

IT is known that the petroleum concessions of the island of Sakhalin have been the occasion for friction between the U.S.S.R. and Japan. The Japanese complain that the U.S.S.R. is pursuing obstructionist tactics that do not permit them to develop their concessions regularly, whereas the Soviets assert that the concessions are subordinate. The disagreement has culminated with the decision of the Soviet tribunals that require the Japanese concessionnaires to pay to the Russian workers' organizations 700 thousand yen for failure to follow completely the labor contract.

The controversy assumes a certain interest because of the importance of the petroleum deposits of Sakhalin. The American statistics give for 1938 a production of about 4,000,000 bbl. for the wells of the island (both Russian and Japanese), whereas in 1936 the total production was 3,212,000 bbl., of which about 2,000,000 were attributed to the Soviet trust and the rest to the Japanese concession.

It seems that the Japanese company, North Sakhalin Oil Company, has applied to the Government at Tokyo for financial aid, stating that it was impossible to develop the concession in full because of the none-too-good relations that exist between Japan and the U.S.S.R. This difficulty is said to have reduced by 75 percent the annual production of the Japanese company.

It is interesting to recall that according to the estimates the petroleum reserves of the island total about 169,000,000 bbl.; but, on the other hand, it is said that the "possible reserves" may reach 2,126,000,000 bbl.

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Catalytic Air-Oxidation of Hydrocarbons

Part 2 (Concluded)

By
RAFAEL FUSSTEIG

AS mentioned in Part 1, pressure and temperature affect the quality of the end products. The use of high pressures (200 atmospheres) and lower temperatures (300°-350°C. improves the yield of alcohols; the use of lower pressures (15-40 atmospheres) and higher temperatures (450°-500°C.) promotes the yield of lower molecular hydrocarbons. Practically, it is impossible to carry out exactly the abovementioned processes separately in the presence of air on account of other factors that change the reactions and cause other intermediary reactions.

There are three possibilities in the decomposition of hydrocarbons by means of air-oxidation action. The first possibility is the decomposition of hydrocarbon molecules and the oxidation of the particles into acids containing fewer carbon atoms than the starting hydrocarbon molecule. Low fatty acids are formed as formic acid, acetic acid, propionic acid, etc. The second possibility is the oxidation of hydrocarbons to alcohols, aldehydes, and acids containing the same number of carbon atoms as the starting hydrocarbon molecule, so that fatty acids as palmitic acid, stearic acid, etc., are obtained. The third possibility is that the above two reactions may take place in parallel, resulting in the formation of oxy-hydrocarbons soluble and insoluble in water. Of course, the ratio of pure hydrocarbons to oxy-hydrocarbons formed in the catalytic air-oxidation depends upon the operating conditions.

The higher the pressure and the greater the contact between the starting material and the air the greater the yield of the oxy-compounds formed in this process. As mentioned, however, the throughput of the air must be thoroughly controlled because of the risk of explosion. Besides, the catalytic air-oxidation cannot exceed certain maximum limits because carbon monoxide and carbon dioxide will be formed, resulting in a decreased yield of pure hydrocarbons and oxy-compounds.

In other words, the more a volume of air enters into chemical reaction with hydrocarbons above the maximum limit, the greater will be the volumes of carbon monoxide and carbon dioxide formed. It is evident from this that the catalytic air-oxidation depends upon limiting a catalytic cracking process to a complete combustion to carbon dioxide, this being dependent upon the temperature, pressure, and length of contact time between the starting material and air. Small volumes of oxygen weaken the necessary linkage of a hydrocarbon atom, splitting it into smaller hydrocarbon particles. An increase of the catalytic air action will result in the formation of aldehydes; further increase causes a higher oxidation into acids, and finally when the maximum air-oxidation is exceeded, the transformation of hydrocarbons into carbon dioxide results. The flow of these reactions can be expressed in general terms as follows: Starting hydrocarbon → smaller hydrocarbon particles → aldehydes → acids → carbon monoxide → carbon dioxide.

A biographical sketch and photograph of the author can be found on page 34 of the December issue of *The Petroleum Engineer*, in connection with Part 1 of this article.

By varying the temperature, the velocity of the throughput, and the time of contact between the starting material and the air, the process may be directed to the formation of predominating amounts of either dehydrogenated products or oxy-compounds. In the first case the product will contain principally unsaturated hydrocarbons having one or two double linkages and aromatic hydrocarbons; in the second case the product will predominate in saturated and unsaturated aldehydes, alcohols, ketones, acids, lactones, phenols, etc.

Piotrowski and Winkler have observed the characteristic dependence of the bound oxygen upon the boiling ranges of separated fractions. They have observed that the lightest and heaviest fractions resulting from the catalytic air-oxidation process contain the greatest amounts of oxygen and the middle fraction contains the least volume of oxygen. The writer believes that the high oxygen content of the heavier fractions is a result of polymerization reactions of certain light oxy-compounds. In the opinion of the writer two types of light oxy-compounds are formed during the catalytic air-oxidation.

The first type is immediately stabilized during the process because of its saturated character in the carbon-oxygen linkage; the second type is unsaturated in the carbon-oxygen linkage, having a tendency toward alkylation and polymerization reactions. These cause the light oxy-hydrocarbons to be transformed into heavier oxy-compounds. In that manner asphaltic acids, and similar heavy oxy-compounds, were formed during the formation of crude petroleum in the earth. The contact between the organic compounds in the earth and the air resulted in various molecule-splitting reactions, leading to the formation of light oxy-hydrocarbons that were then submitted to different polymerization processes. Consequently not only acids but also asphaltic compounds as well as resin-like hydrocarbons were formed. As far as the middle fraction is concerned, it contains little oxygen because of its tendency to be only split and dehydrogenated. From these considerations it may be concluded that all gaseous, liquid, and solid hydrocarbons can be submitted to catalytic air-oxidation, under various operating conditions that will determine whether aldehydes, ketones, alcohols, acids, etc., are formed or they may be dehydrogenated to form unsaturated hydrocarbons in the first phase, which are, in the later phases, starting materials for different reactions.

It is also very important to mention here that the oxidation of higher-molecular hydrocarbons by the action of air at high temperature to form better asphalts is also a catalytic air-oxidation process. The catalytic air-oxidation has in this case the purpose of

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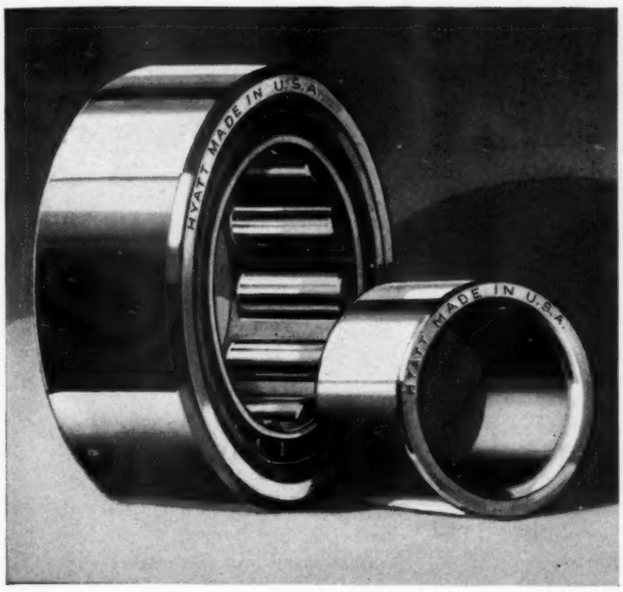

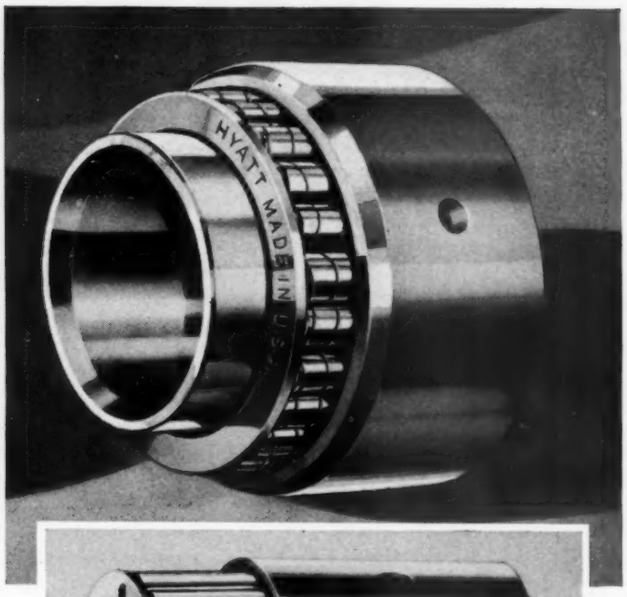

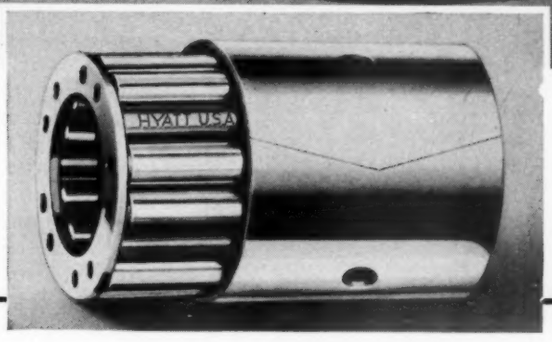

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transforming the coke content of asphalts into carbon dioxide. Furthermore, this process can cause the splitting of highly unsaturated higher-molecular hydrocarbons to form higher-saturated resins and result in the split carbon atoms entering into chemical reaction with oxygen of the air, transforming them into carbon dioxide.

In other words, the catalytic air-oxidation process in the improvement of asphalts causes a rearrangement of the inferior hydrocarbons to form resins and asphaltenes. Because of this a proper ratio of asphaltenic-resinous-paraffinic hydrocarbons is formed that increases the quality of the asphalt. For this reason non-asphaltic crude oils that do not show the necessary ratio of asphaltenic-resinous-paraffinic hydrocarbons can be improved by blowing air through the concentrated residuum, using proper operating conditions.

On the other hand, higher-molecular hydrocarbons such as tar, asphalt, coal, etc., can be submitted to the catalytic air-oxidation process to form smaller oxy-hydrocarbons. As such materials contain very small amounts of disposable hydrogen, however, very small yields of lower-molecular oxy-hydrocarbons will be formed and the result will be that the remaining high unsaturated particles will be condensed and polymerized into solid oxy-hydrocarbons, and even into coke.

To prevent these condensation and polymerization reactions leading to undesirable results, a simultaneous hydrogenation process should be used. This will result in the enrichment of the hydrogen atoms in the sphere of the reaction, so that the carbon atoms with two active linkages remain active a longer time. Consequently, the deposition of coke decreases. The saturation of the split unsaturated hydrocarbons takes place and the $=HC_2$ molecules that are formed are then changed to smaller oxy-hydrocarbons.

Of course, this combined oxidation-hydrogenation process must be directed to avoid high oxidation reactions, i.e., the oxidation reactions must be closely controlled to avoid an explosion. For this reason the process cannot be conducted in a single stage because oxygen and hydrogen cannot be introduced into the same reaction chamber. In other words, the oxidation reactions cannot occur simultaneously with the hydrogenation reactions. There are different reasons that prevent simultaneous flow of the two reactions. First of all, the hydrogen enters into reaction with oxygen under the catalytic air-oxidation conditions causing an explosion. Secondly, the tendency of oxygen and hydrogen to enter simultaneously into reaction with the split hydrocarbon atoms weakens the sphere of reactions so that other distinct intermediary reactions occur. As a consequence, a "wild" flow of reactions results that yields undesirable products, and finally the simultaneous action of hydrogen and oxygen causes a formation of light oxy-hydrocarbons having very weak oxygen linkages possessing a tendency to polymerize into higher oxidation products.

This process, therefore, should take place in two stages. In the first phase the destructive hydrogenation should take place; in the second phase the catalytic air-oxidation process should occur. Each of these reactions must, of course, occur in a separate reaction chamber, and the starting material must be treated in the vapor phase. A very interesting patent[10] proposes hydrogenation of the oil prior to oxidation. In this process hydrocarbon oils containing paraffin wax are treated by hydrogen at a temperature of 400°-470°C. under a pressure of 200 atmospheres in the presence of oxides as catalyst.

The hydrocarbon atoms thus hydrogenated are cooled and directed to the second reaction chamber in which the catalytic air-oxidation reaction takes place. Under a normal pressure and a temperature of 180°C., the hydrogenated hydrocarbon particles will be oxidated in the chamber to form light stable oxy-hydrocarbons. When using catalysts such as stearate or permanganate, the air-oxidation process will result in a good yield of fatty acids.

It is interesting to mention here that steam can also be used in the catalytic oxidation of hydrocarbons. The manufacture of water gas from solid coal is nothing but the catalytic oxidation process using heated steam. Under the influence of a proper catalyst and proper operating conditions the steam is split into oxygen and nascent hydrogen, the oxygen entering into chemical reaction with the carbon molecules to form carbon dioxide. Under milder conditions, however, the catalytic oxygen action of the heated steam only causes the formation of oxy-hydrocarbons.

In this case active labile OH-molecules are formed that migrate during the process to form true aldehydes, alcohols, ketones, and phenols. According to this phenomenon, the Fischer process is able to produce a mixture of alcohols from the water gas. Of course, the catalytic oxidation process by means of the steam can also be carried out on hydrocarbons of the petroleum type. Thus gaseous, liquid, and solid hydrocarbons can be submitted to the steam oxidation-cracking process in the vapor phase, using proper operating conditions and a proper catalyst.

Different catalysts in the form of oxides can also be used as catalytic oxidation material, especially in the cracking processes of higher-molecular hydrocarbons. The reason for this lies in the deposition of coke during the cracking reactions. The metallic oxide is able to oxidate the remaining carbon atoms into carbon dioxide thus preventing the deposition of coke. Ramage[11] proposes the use of Fe_2O_3, which, being reduced to FeO, attacks the formed carbon by means of the split oxygen, transforming it into carbon dioxide. At the same time split hydrogen atoms also enter into chemical reaction with the split oxygen forming water that in the further reactions enters into chemical reaction with the FeO resulting in the formation of Fe_2O_3 and the splitting of hydrogen.

All catalysts in the form of oxides improve the flow of the reactions during the cracking process because the remaining carbon atoms are not allowed to enter into chemical reaction with the split hydrocarbons. Thus the condensation and polymerization process is prevented, the yield of gasoline is increased, and the amount of coke formed is decreased. Of course, the volume of gas formed is increased slightly, as more carbon dioxide molecules are formed. A smaller volume of asphaltic and resin-like compounds is obtained as the conditions favor the formation of lower molecular hydrocarbons.

Reviewing the factors discussed in this article, it may be concluded that catalytic air-oxidation plays a very important part in all branches of the oil-refining industry. It is a decisive factor in the distillation process in that it influences the type of petroleum products obtained. The longer the contact time between the air and the hydrocarbons during the distillation, the more hydrocarbons will be submitted to different decomposition reactions. Pipe-still operations, therefore, show better results than those of the shell-still, because of the short contact time between the air and the heated starting material. Also important is the concentration of the air during the distillation process. Consequently, the purpose of a high vacuum in distillation is not only to decrease the boiling points of the hydrocarbons but also to dilute the air-medium and thus decrease the cracking oxidation reactions.

Furthermore, the catalytic air-action is used in the improvement of in-

[10]Brit. P. 369,852.

[11]U.S.P. 1,365,849.

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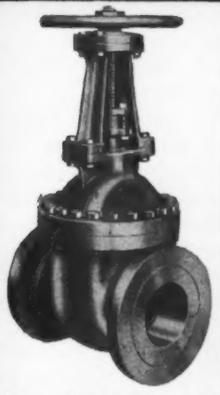

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ferior asphalts by rearrangement of the inferior hydrocarbons to form true resins and asphaltenes. Conversely, this oxygenation also creates favorable reactions during the cracking of higher-molecular hydrocarbons into gasoline. The oxygen in this instance binds the carbon atoms that have not previously found available hydrogen atoms during their fluctuation. Of course, air can cause serious explosions if not controlled properly; it is better, therefore, to use metallic oxides, the oxygen of which enters into oxidation reactions that retard the formation of coke and increase the yield of lower molecular hydrocarbons.

The catalytic oxygen-reaction exhibits a similar characteristic in the destructive hydrogenation processes. It is very convenient, therefore, to use catalysts in the form of oxides that aid in controlling the rate of reaction so that only desirable products are obtained. The formation of water gas as a source of material for the manufacture of hydrocarbons and oxy-hydrocarbons can also be considered as a result of the action of the catalytic air-oxidation process. The difference between the hydrogenation of hydrocarbons and the production of gasoline and other products lies only in the manner of operation. In the first case the oxygen acts as a joiner that, after the carbon and hydrogen atoms are combined, is split from the molecule, then joining other carbon-hydrogen atoms; in the second case the oxygen enters into reaction with split carbon atoms forming carbon monoxide, which then subsequently combines with hydrogen atoms in various reactions to form true hydrocarbons. In the first case very small amounts of oxygen are required; in the second case very large volumes of oxygen must be used. Metallic oxides, therefore, are suitable as catalysts in the first case, but in the second, large volumes of steam are necessary.

Finally, catalytic air-oxidation plays a very important role in the manufacture of organic acids, alcohols, ketones, aldehydes, etc., from gaseous, liquid, and solid hydrocarbons. In this process, catalysts and operating conditions may be selected to control the composition and quality of the products obtained.

P 683.7

Machine for Wrapping Diaphragms of Large Displacement Meters

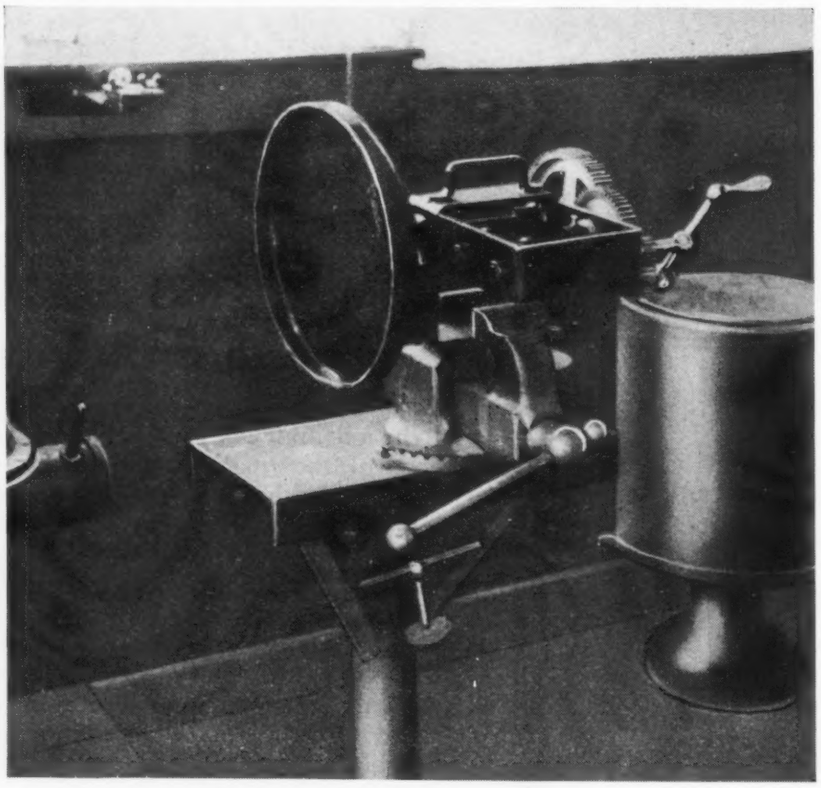
By ROY W. PARKER, Oklahoma Natural Gas Company

ANY repairman who has hand-wrapped meter diaphragms will recall a few disturbed moments. Hand-wrapping is not only a slow procedure, but it is difficult to do a good, neat job.

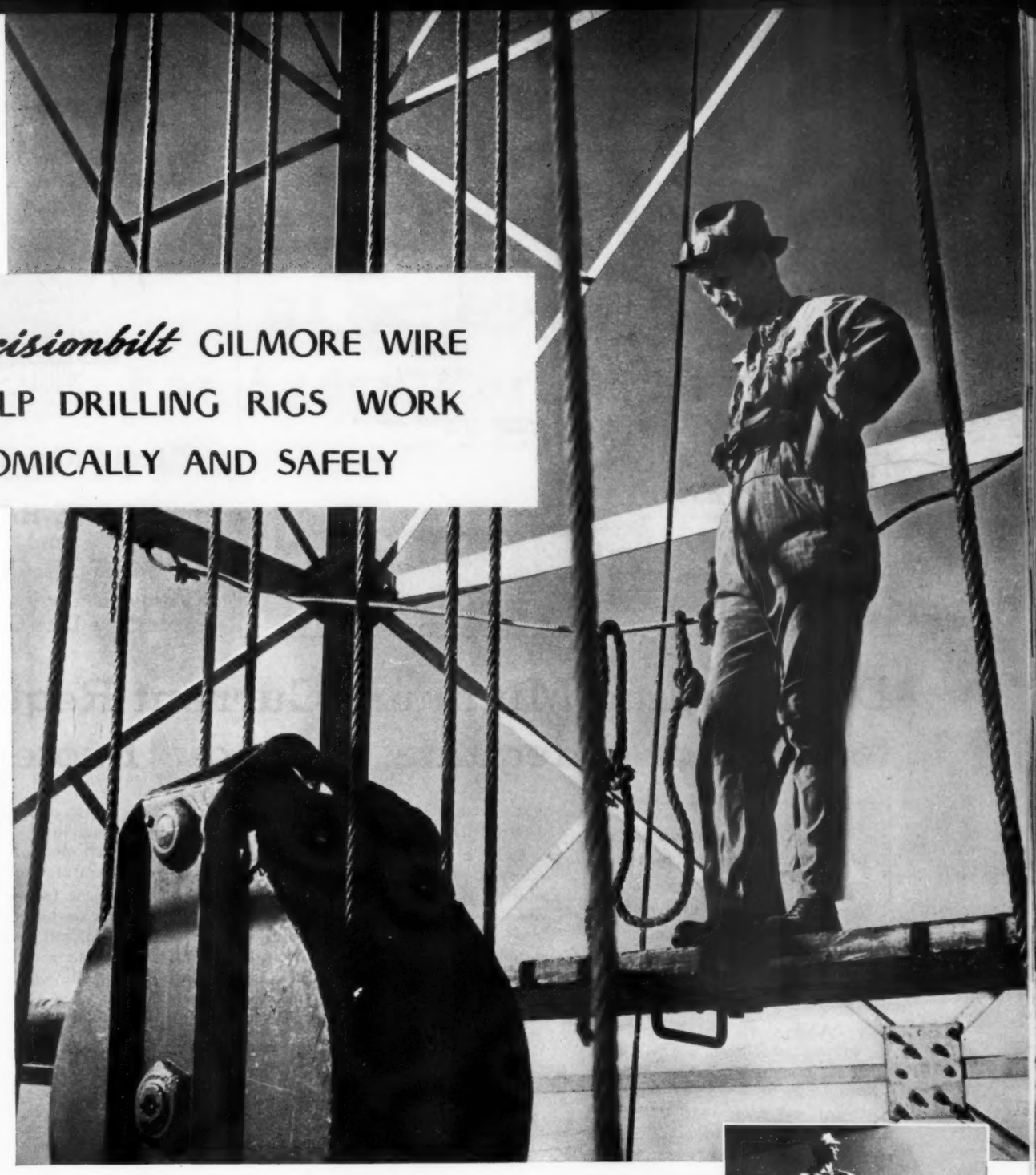
In the interest of lower repair cost on this type of meter, the shop foreman of the Oklahoma Natural Gas Company, Harry Wilson, and the repairmen, offered their ideas as to a better method. The result was a machine that will wrap about 30 diaphragms per day as compared to 5 or 6 by the hand method, and the wrapped diaphragm is comparable to a factory job as to wire strand evenness and tautness.

This machine, as shown in the accompanying illustration, is of simple construction and inexpensive compared to the savings effected. The general specifications are as follows: The frame is 8 in. wide, 10 in. long, 3 in. deep in front, and 8 in. deep where the drumshaft extends to the large master cogwheel. This main shaft is $\frac{7}{8}$-in. cold-rolled steel and the other two auxiliary cogwheel shafts are $\frac{3}{4}$ in. in diameter.

The ratio of crank revolution to diaphragm drum revolution is 26 to 1. The three power gears are a 12-cog crank gear to a 50-cog intermediate gear to the 76-cog main drive gear. The idling gear below the crank gear has 18 cogs. The main drumshaft is threaded to take a left-hand female thread on the drums. The diaphragm drums are made to fit the different sizes and are fashioned like a car brake drum. The diaphragm plate is fitted over the drum and an adjustable set screw on the rim gives the proper tension. In the illustration, on the wall at the left is situated the clamp through which the wire passes and by which the desired tension is obtained. Small fibre blocks between metal blocks through which the wire passes serve as a brake to the wire being wrapped around the diaphragm. Thumb-screws through these plates can be tightened to give the proper tension on the wire.



This machine will wrap 30 meter diaphragms per day compared to 5 or 6 by the hand method



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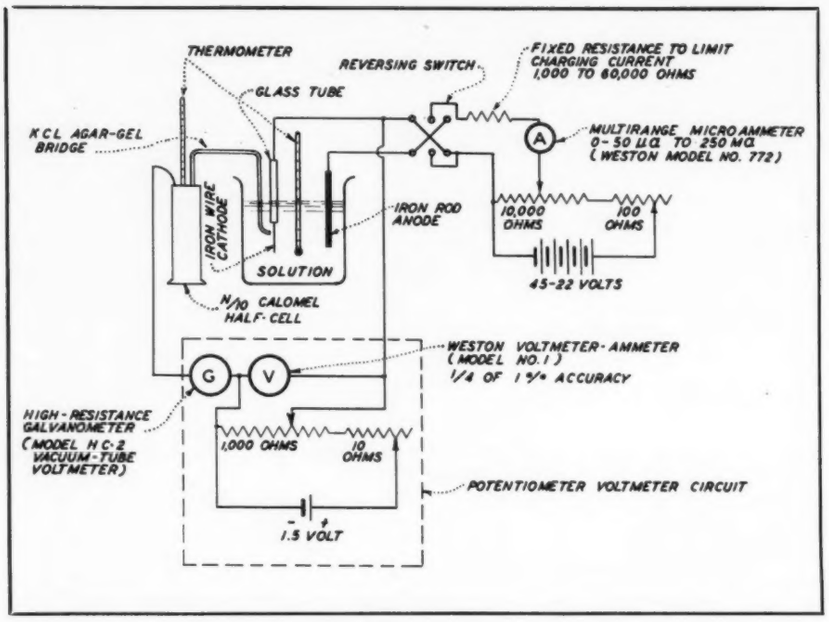

Fig. 1. Circuit diagram for determination of the protective potential

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Part 2 (Concluded)

By DAVE HARRELL
and
MILTON CLERC
Corrosion Engineers, Houston Pipe Line Company

Determining Minimum Current Required to Provide Adequate Cathodic Protection

Biographical sketches and photographs of the authors can be found on page 38 of the October issue of *The Petroleum Engineeer,* in connection with Part 1 of this article.

IN PART 1 of this article[1] the writers established a theoretical half-cell protective potential between pipe and soil of — 0.2853 volt. The statement was made that it was impossible to conceive of corrosive soil possessing infinite resistance. Hence, although we speak of protective potentials, the problem really concerns the current that flows in the circuit because of this difference of potential.

Part 2 of the article will be devoted to showing what happens to the current curve when protective potential is reached at the cathode and how laboratory experiments yield values for this protective potential that very nearly coincide with the calculated theoretical value.

As it is desired to obtain relative values of the solution current and the solution to cathode potentials, the advisability of keeping the cathode relatively of as small an exposed area as possible immediately presented itself. It was also seen to be absolutely necessary that no current be drawn from the circuit by the measuring device and that an accurate comparison standard cell be present in the circuit at all times. The cell must of course have a known temperature correction factor.

With all these factors in mind the apparatus was set up as shown in Fig. 1. The N/10 calomel electrode is shown with thermometer attached and its potential to its solution is expressed by the equation: $E_{n/10} - E_{liq} = +0.6130 + (t - 18)\,0.0008$ where "t" is in °C.

[1] *The Petroleum Engineer,* October, 1939.

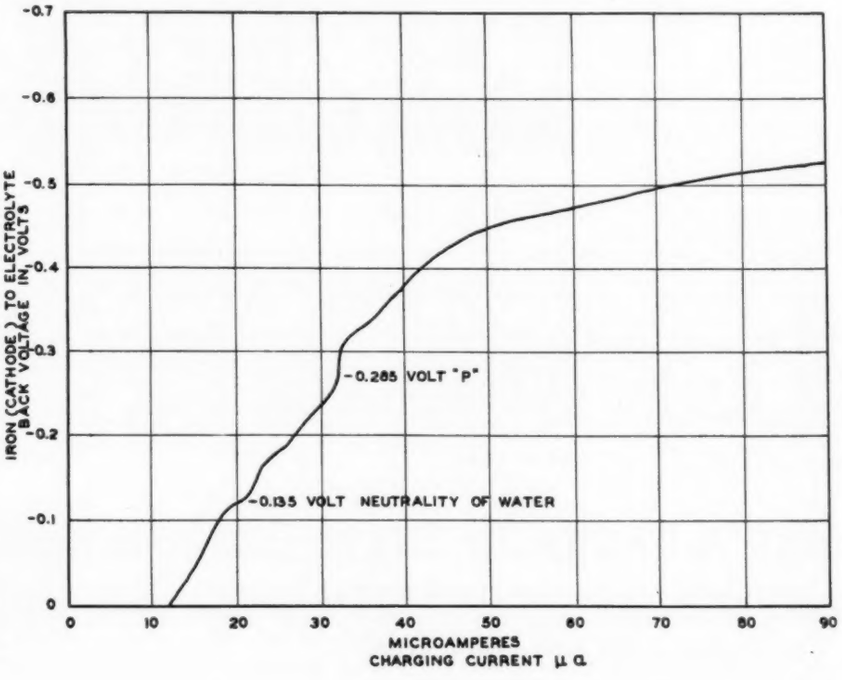

Fig. 2. Curve showing rise of cathode-solution E.M.F. with increase of charging current. Cathode: iron wire 2 cm. long. Temperature: 25°C; 77°F. Solution: tap water

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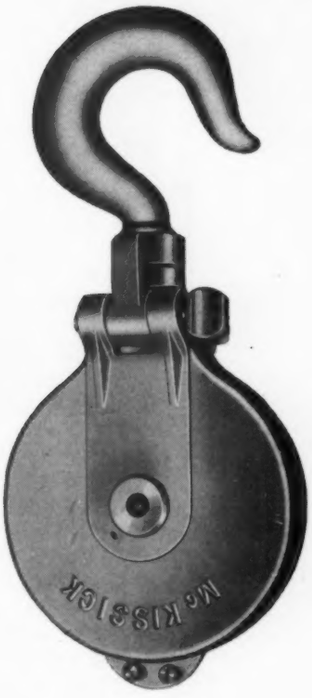

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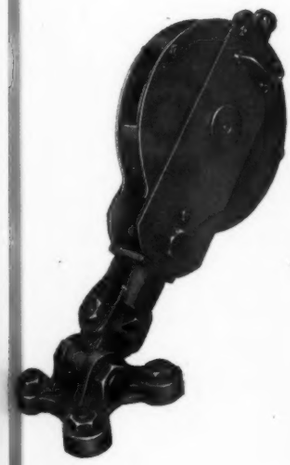

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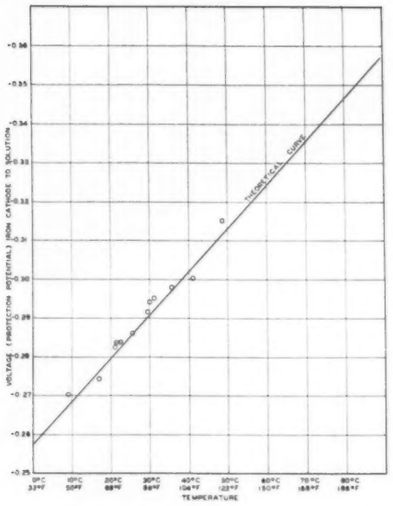


Fig. 3. Graph showing rise in value of protection potential with rise in temperature

The potential of the liquid referred to the normal hydrogen electrode is $E_{liq} - E_h = -0.2800 - 0.00074\,(t - 18)$ where "t" is again expressed in °C.

It will be noted that a potassium chloride agar-gel bridge connects the N/10 calomel electrode to the fine iron wire used as an experimental cathode. The beak of the glass tubing of this bridge should make contact with the solution immediately surrounding the cathode wire to avoid solution "ir" drops. The cathode wire was of C.P. iron and No. 26 gauge and two centimeters long. The electronic bridge was made from a saturated solution of potassium chloride mixed with agar-gel.

A special vacuum-tube voltmeter having an input resistance of 5 meg. ohms was used as a balancing galvanometer between the potentiometer voltmeter circuit and the calomel electrode. The solution current was measured as accurately as possible by the multirange micro-ammeter shown to the right of the reversing switch in Fig. 1.

Ordinary tap water was used as the first electrolyte and a very interesting curve drawn (Fig. 2). On this curve will be noted two ripples; one occuring at a point on the curve where the iron wire reached a solution potential of —0.135, and the other at —0.285 volt. The first of these ripples was undoubtedly due to the fact that the tap water used was slightly acid and the alkali produced at the cathode neutralized the water in the immediate vicinity. When this neutralization was complete, hydroxyl ions could accumulate at the cathode at the same rate until a point was reached at which the slope of the curve was maximum and a very marked increase in cathode potential was obtained per unit current applied. This point is considered that at which electrical protective potential of iron is established; measured in the laboratory to be —0.285 volt. This compares very favorably with the calculated value of —0.2853.

Table 1 illustrates the method of computing the results of the experiment and Table 2 shows the comparative results for various electrolytes examined.

It will be noted from Table 2 that the protective potential does not vary with a change in solutions, the changes noted being due to differences in temperature. This leads to the belief that the greatest influencing factor on protective potential is temperature.

Fig. 3 shows the close proximinity to a straight-line curve that the actual measured points describe. It is possible to assume that this is a straight-line curve and that its theoretical extension would be as shown. It is noted from this curve that protective potential at 122°F. is no longer —0.2853 but has taken on a new value in the vicinity of —0.315 volt. Also, at a theoretical 186°F. it would be about —0.347. This straight-line curve relation was predicted by the equation:

$$\frac{E_p}{E_2} = \frac{T_1}{T_2}$$

which was discussed in Part 1 of this article. It was stated that the calculated protective potential should be corrected for temperature in accordance with the equation:

$E_{p_2} = -0.2853 - 0.00096\,(t - 25)$, where t is in °C.

$E_{p_2} = -0.2853 - 0.00053\,(t - 77)$, where t is in °F.

The experimental protective potentials observed in Table 2 were averaged and corrected to 25°C. where an average observed potential of —0.283 volt was obtained.

TABLE 1

I Charging current in milliamperes	E Voltage referred to calomel cell	dI Change in current in milliamperes	dE Change in solution potential at cathode volts	$\frac{dE}{dI}$
0.293	—0.950			
0.150	—0.939	0.143	0.011	0.0767
0.086	—0.924	0.064	0.015	0.234
0.069	—0.917	0.017	0.007	0.410
0.061	—0.908	0.008	0.009	0.12
0.051	—0.900	0.010	0.008	0.8
0.033	—0.883	0.018	0.017	0.945
0.015	—0.863	0.018	0.02	0.900
0	—0.855	0.015	0.008	0.533

Average protection potential, —0.9145
Temperature of solution, 82°F. or 27.78°C.
Temperature of calomel cell, 83°F. or 28.33°C.
Voltage of calomel cell, —0.6214
Protective potential referred to solution, —0.293
Calculated value at 0°C., —0.289

TABLE 2

Solution, $Fe SO_4$ plus - - -	Concentration of salt or base	Experimental protective potential, negative volts	Temperature, °F.	Calculated protective potential
Acid water	Not measured	—0.285	77	—0.2853
Na OH	N/100	—0.291	90	—0.292
Na OH	N/100	—0.292	88	—0.291
KCl	N/10	—0.316	118	—0.311
KCl	N/10	—0.270	48	—0.272
KCl	N/10	—0.284	73	—0.282
KCl	N/10	—0.282	70	—0.281
NaCl	N/10	—0.274	64	—0.278
NaCl	N/10	—0.286	89	—0.291
Acid tap water	Not measured	—0.294	110	—0.306
Acid tap water	Not measured	—0.292	101	—0.300
Na OH	N/100	—0.278	86	—0.290
NaCl	N/100	—0.282	81	—0.287
NaCl	N/10	—0.293	83	—0.289
Acid tap water	Not measured	—0.295	86	—0.290
$FeSO_4$	Saturated	—0.285	83	—0.289
$FeSO_4$	Saturated	—0.282	84	—0.290
NaCl	N/10	—0.286	78	—0.286
Averages		—0.287	84	

All protective potentials averaged and reduced to 25°C., 77°F., —0.283
Calculated value from Part 1 of this article, —0.2853

Proper Installation of Pumping Unit Essential to Satisfactory Service

Correct alignment of unit on foundation may be obtained by use of bolt templates and grout sleeves

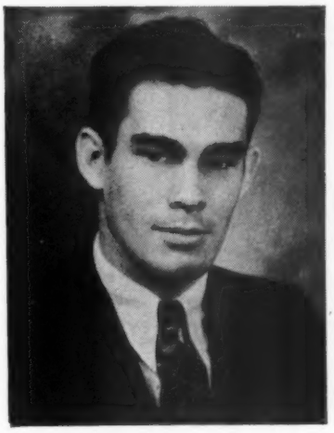
By

KENNETH N. MILLS

Chief Engineer, American Manufacturing Company of Texas

THE selection of a pumping unit of the proper size for a given well does not give complete assurance that the unit will render satisfactory service, because the service obtained from the unit will depend to a considerable extent upon how the unit is installed and serviced. If the unit is properly installed, all loads imposed on it will be applied in the most favorable manner, and none of its members or bearings will be subjected to the unnecessary loads incident to some installation errors. Also, the loads will be transferred from the unit to the foundation in a manner that will not subject the foundation bolts to unnecessary loads and possible failure.

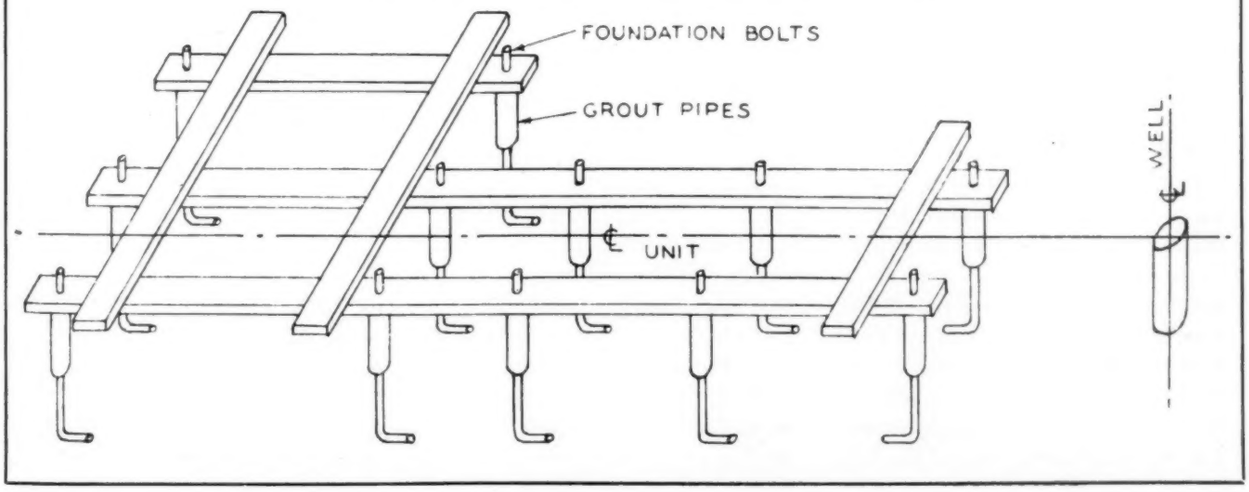
One of the most common errors involving pumping unit foundations is misalignment of the pumping unit relative to the wellhead. To attain the most favorable loading on all members, the center-line of the unit must intersect the center of the well. If this alignment is not obtained, the center of the polished-rod hanger will not be coincident with the center line of the well, unless the beam is oriented or rotated with respect to the center line of the unit. If the beam on a twin-crank unit is oriented in this manner, the center of the beam equalizer bearing will not be vertically over the center of the speed reducer. If the beam on a single crank unit is oriented in this manner, the center of the beam pitman bearing will not be vertically over the center of the wristpin bearing. If these points are not properly



KENNETH N. MILLS

received a B.S. degree in mechanical engineering from Rice Institute, Houston, Texas, in 1933—He joined the engineering staff of the American Manufacturing Company of Texas, Fort Worth, in 1934 and was placed in charge of that department in 1935—During his association with the petroleum industry he has devoted considerable time to the analytical study of problems encountered in oil-well pumping.

Fig. 1. A typical templet for a twin crank unit, used to locate foundation bolts and thus eliminate certain foundation errors



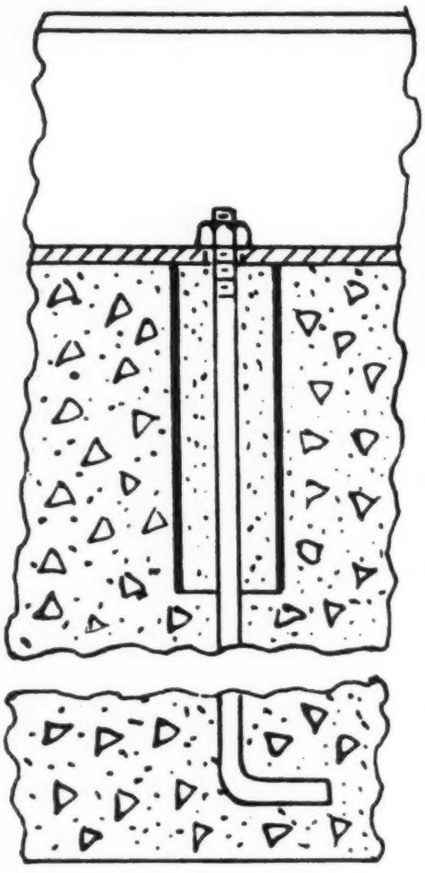


Fig. 2. Correct foundation-bolt installation

aligned, a lateral load will be imposed on the rear end of the beam, and a torsional moment will be imposed on the samson post. The lateral load on the beam will set up bending stresses that will add directly to those normally existing in the beam, and if the intensity of these combined stresses is great enough, they will cause the beam to fail. The torsional moment imposed on the samson post may induce additional stresses in the samson post members that will contribute to failure of the samson post as well.

If the unit includes a bell crank or V-type under-beam take-off for pumping a second well, the center line of the unit must intersect and be parallel to the vertical plane of the rod line as it enters the pumping unit. If the pumping unit is not properly aligned with the rod line to the second well, the load distribution across the pull-rod bearing on the take-off to the second well will not be uniform, and the load will not be uniformly distributed between the two pull straps. The non-uniform loading imposed on the pull-strap bearing will cause the bearing pressure to become very high on one side of the bearing and very low on the other side of the bearing, resulting in decreased life of the bearing. The unequal distribution of the load on the pull straps can cause one of them to fail, if the misalignment is great, because, in addition to increasing the

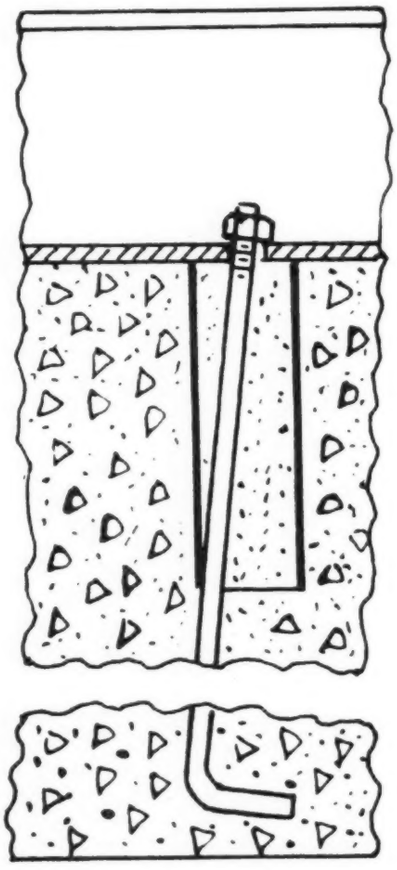


Fig. 3. The grout-pipe was located properly but careless placement of the concrete resulted in the bolt-head being pushed "out of plumb"

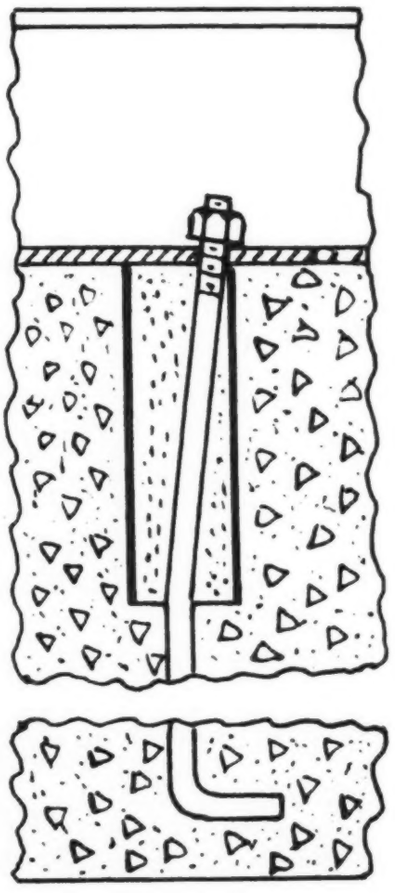
tensile load in one of the pull straps, it induces bending stresses in the pull straps.

In the case of a V-type under-beam take-off, the lateral load imposed on its lower end by the misalignment will set-up bending stresses in its members. As these stresses add to those normally existing in the members, they may increase the maximum stress in these members, causing failure.

The above types of foundation errors can be eliminated by using a templet to locate the foundation bolts. A typical templet of this type for a twin crank unit is shown in Fig. 1. This templet has holes for each foundation bolt, and the grout pipes are nailed to its underside. A template of this type can be aligned with the well by stretching a line between the rear center of the unit and the center of the well, and adjusting the front center of the unit to coincide with this center line. When the templet is thus located, it should be securely anchored so it will not be displaced when the concrete is poured into the foundation pit.

The use of grout pipes has saved many foundation blocks from the

Fig. 4. Errors in locating bolts should not be corrected by resorting to this much bolt-bending



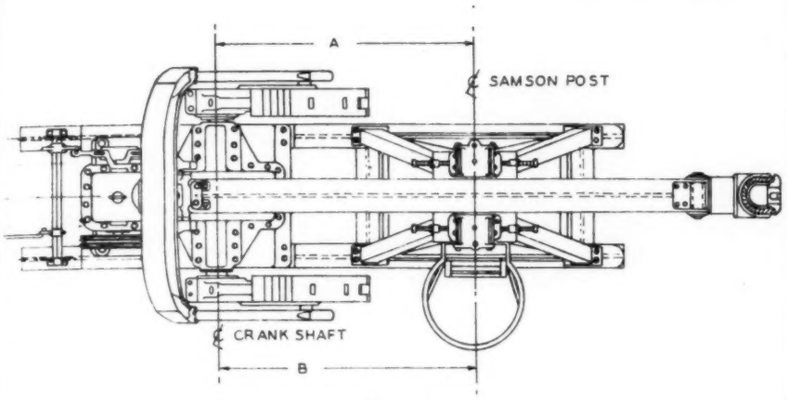


Fig. 5
Aligning double-crank installations

blasting powder, but it has caused innumerable foundation bolt failures. Grout pipes can and should be used in all foundations to permit correcting small errors that are almost impossible to eliminate, but they should not be considered as a means of correcting large unnecessary foundation errors. The ideal foundation bolt installation is shown in Fig. 2. When a foundation bolt is installed in this manner, the loads imposed on it are applied uniformly over the undersurface of the nut, and are transferred directly to the bolt as pure tension. Two common types of misuse of grout pipes are shown in Figs. 3 and 4. In each of these installations, the loads are not applied uniformly over the undersurface of the nut, but are concentrated on one side of the nut. The non-uniform application of the load to the nut sets-up bending stresses in the foundation bolt. As these bending stresses add to the tensile stress normally existing in the bolt, they reduce the load capacity of the bolt and may cause it to fail.

Foundation bolts on which the nuts are not snug will cause the foundation bolt load to be carried by the foundation bolts on which the nuts are snug, and as the latter are called on to carry more than their share of the load, failure may result. If all nuts are loose, impact loads will be imposed on the foundation bolts inducing high stresses and causing the bolts to fail.

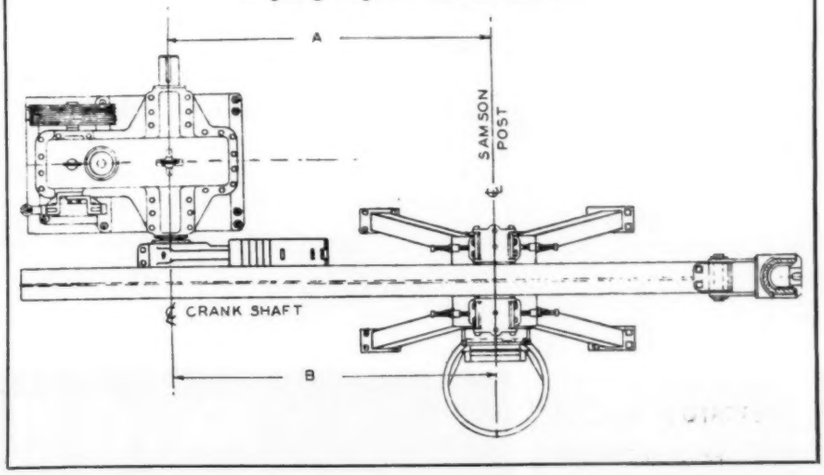
If the surface of the foundation block is not smooth and level, one or more foundation bolts may be carrying more than its share of the load. This condition has caused numerous foundation bolt failures, and the possibility of this occurring can be reduced to a minimum by placing a 1-in. grout between the equipment and the foundation block, after the equipment has been leveled by the use of shims. It is important to note that the shims should be removed after the grout has set.

Lateral beam loads and the accompanying torsional samson post loads can be imposed on a unit by conditions other than beam misalignment. If the plane in which the beam oscillates is not parallel to the planes in which the centers of the wristpins rotate, a lateral load will be imposed on the beam. If the plane of beam oscillation is not coincident with the center line of the well, a lateral load will be imposed on the beam. The possibility of a lateral load being imposed on the beam by its traveling diagonally to the polished rod can be eliminated by having the saddleshaft level. The wristpin centers will travel in a plane parallel to the beam only if the crankshaft is parallel to the saddleshaft. If the unit has a steel subbase, a horizontal plane through the center line of the crankshaft will be parallel to a horizontal plane through the center line of the saddleshaft, but due to the clearances between the reducer foundation bolts and their holes, vertical planes through the center lines of these shafts may not be parallel. These two shafts can be aligned in the vertical plane by locating the center line of the samson post on the frame of the unit and adjusting the location of the reducer until the distances A and B, as shown in Figs. 5 and 6, are equal.

If the reducer and samson post are mounted directly on a concrete foundation, the saddleshaft and crankshaft can be aligned in the horizontal plane by leveling each, and they can be aligned in the vertical plane by the foregoing method.

These rules for the proper installation of a pumping unit are all simple, and the cost of abiding by them is small when compared to the return received. This return will manifest itself in the form of lower maintenance cost and less loss of production due to shutdowns.

Fig. 6
Aligning single-crank installations



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Mechanical Practicability of Electrical Logging While Drilling

Special equipment gives a continuous record at the wellhead while drilling is in progress. The results obtained on six wells demonstrate the feasibility of a new system that may have a far-reaching influence in advancing modern drilling technique

By DAVID G. HAWTHORN, Development Engineer, Amerada Petroleum Corporation and JOHN E. OWEN, Physicist, Geophysical Research Corporation

ROTARY drilling, with ample justification has been termed "drilling in the dark." When normal rotary drilling is in progress, little is definitely known and positive data are not immediately available on the nature and characteristics of the formation being penetrated by the bit.

An increasingly insistent need has been felt for the development of means by which tangible information could be had instantly; this need has been particularly great in the drilling of wildcat and exploratory wells. Greater depths and higher drilling speeds, besides accentuating this need, have also made the problem become increasingly critical. Potential oil- and gas-producing zones may be drilled through and passed by without being detected. Experience indicates that when this happens many of these zones may never be discovered. As protection against this contingency, conventional and wire-line coring have been resorted to in increasingly greater degree, until exploratory drilling costs in many cases have become inordinately high. High drilling costs and the inherent limitations in coring results have caused a recent trend in the reverse direction toward less costly and more expedient methods. These, in some cases, may prove adequate, but the basic difficulty has not been altered or removed.

The overcoming of this inherent drawback to rotary drilling has been the hard-sought-after objective of oil men for many years. The development of electrical logging is an approach to a solution of the problem. Electrical logging has been established and proved in the United States during the last ten years, and today it is recognized as one of the outstanding contributions to scientific advancement in the art of drilling and prospecting for oil. It is now accepted as one of the most useful aids to prospecting that are available.

The system herein described, whereby a well is logged electrically while it is being drilled, is an advanced application of electrical logging. As now developed, the system amply demonstrates the mechanical practicability of overcoming an inherently difficult problem involved in rotary drilling.

The Amerada Petroleum Corporation, assisted by the laboratory facilities of the Geophysical Research Corporation, for several years has been developing and testing a special rotary drill stem and accompanying auxiliary equipment, with which to make possible the procuring of electrical well logs simultaneously with drilling. The basic plan behind the development has been the use of the drilling bit as the exploring electrode from which electrical readings might be obtained and recorded at the surface. To accomplish this it has been necessary to incorpo-

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was graduated from the University of Colorado at Boulder in the class of 1924 with a Bachelor of Science degree in mechanical engineering—In 1928 he received his "Degree Mechanical Engineer" from the same university—Beginning work in the summer of 1924 in the geological department of the Marland Oil Company of Oklahoma, he was later transferred to the production department, and then to production engineering—In 1929 he joined the Barnsdall Oil Company to take charge of repressuring work, later to become involved in the study of bottom-hole pressures, and then to become Gulf Coast engineer—The first of 1935 he became associated with the Amerada Petroleum Corporation, working in his present capacity as development engineer—During the last five years his time has been spent almost entirely on the development project described in this article.

JOHN E. OWEN

was graduated from the University of Oklahoma, receiving his bachelor's degree in mathematics in 1926, and a master's degree in physics in 1928—In 1926-27 he was employed by the Marland Oil Company in the geophysical department in the Gulf Coast—In the summer of 1928 he went to work for the Geophysical Research Corporation in Louisiana, and later that year was transferred to the laboratory of that company at Bloomfield, New Jersey, as geophysicist, moving to Tulsa, Oklahoma, when the laboratory was moved there in 1933—In addition to continuing research work in geophysics, for the last three years he has been engaged in special experimental and development work for the Amerada Petroleum Corporation—This work has included the development of the recording and testing equipment described in this article.

rate, as an integral part of the drill stem, an electric circuit and to insulate by suitable means the bit from the pipe. It was further necessary to provide recording apparatus and means for connecting this apparatus to the drill-stem circuit.

Approximately 6000 ft. of special drill pipe has been constructed. Two insulated drill collars and a special kelly and kelly subs have been fabricated to complete the drill stem. Recording equipment has been designed, assembled, and mounted in a house trailer in which are also placed miscellaneous control and testing apparatus. Insulated cables running from the trailer to the derrick connect the recording apparatus to the electrical circuit in the drill stem.

This equipment has been used to drill six wells scattered throughout the Mid-Continent and Gulf Coast areas. A record of these tests is shown in Table 1. Of the 27,267 ft. of hole drilled and available for logging, 24,320 ft. of record was successfully obtained. An overall percentage figure of 89.2 percent might be shown, but this figure has little significance without being qualified. While drilling the first three test wells a serious mechanical defect was present in the drill stem, causing considerable trouble in maintaining proper circuit. Even the relatively satisfactory figures of 91.00 percent and 93.29 percent, obtained in the second and third tests respectively, are somewhat misleading, for they were obtained at considerable extra work and expense. This extra work was not done, however, for the primary purpose of obtaining additional records, but rather to gain further knowledge and experience with the drill stem under actual drilling service. After drilling the third well, the mechanical difficulty was found and corrected. From this time on results from the equipment were more encouraging and the percentage figures for the last three tests speak for themselves. In the case of the Kleiner well in Haskell County, Texas, drilling was in progress for more than nine weeks, and only two or three times did trouble of any consequence occur. From the table will be seen the continuously increasing percentage of record obtained. This is particularly significant, especially when considering the fact that on each successive well operating troubles and interference to drilling became less and less.

The electrical record taken while drilling is similar to any conventional electrical log, except that potentials and resistances are continuously measured and recorded on a meter while drilling is in progress. The chart is in plain view of the observer at all times. Formation resistance is recorded on the right and formation potential on the left. Both measurements are recorded against the well depth as the other coordinate.

At the completion of drilling, each well drilled was electrically surveyed by the conventional method. The records obtained while drilling are in most instances similar if not identical to the conventional logs; however, in a few instances very interesting differences occur. Some of these may be observed in the accompanying illustration of the records. Significant comparisons may be made at depths of 2670 ft., 2715 ft., 2775 ft., 2800 ft., and 2870 ft. A general comparison of the two charts regarding similarity and amount of detail is particularly interesting, especially considering the extreme difference in the two logging methods. The dotted line at 2875 ft. on the resistance curve indicates where a core was taken, the dotted part of the curve being the actual reading obtained while reaming the core hole.

TABLE 1
Drilling Record

Well and location	Started	Completed	Drilled			Feet of drilling record obtained	Percent
			From ft.	To ft.	Total ft.		
1. No. 2 W. D. Knight, Langston field, Logan County, Okla.	1-23-38	2-28-38	287	4977	4690	3143	67.01
2. No. 2 Ralph C. Smith, Fairbanks field, Harris County, Texas	6-30-38	7-13-38	77	5155	5078	4621	91.00
3. No. 1 J. H. Emmott, Fairbanks field, Harris County, Texas	9-28-38	10- 7-38	1208	5203	3995	3727	93.29
4. No. 4 K. C. Silberberg, Fairbanks field, Harris County, Texas	2-11-39	2-18-39	1213	5412	4199	3952	94.12
5. No. 1 Chas. Kleiner, Wildcat, Haskell County, Texas	3-26-39	5-25-39	247	5607	5360	5047	94.16
6. No. 10 Hettie Berk, Cavuga field, Freestone County, Texas	11-18-39	12- 1-39	80	4025	3945	3830	97.08*
Total feet of hole drilled					27,267		
Total feet of hole electrically logged while drilling						24,320	

*This figure reached as a result of increasing experience and the elimination of certain mechanical difficulties to the point that interference with normal rig and drilling operations became negligible.

The Electric Circuit

Both the single- and multiple-electrode systems are in common use today for electrically logging wells. The multiple-electrode system, in which three or more electrodes are used, requires a separate insulated conductor for each electrode, whereas in the single-electrode system, one electrode and one insulated lead are all that are required. At the time of considering the incorporation of an electric circuit in the rotary drill stem and using the bit as the exploring electrode, mechanical practicability favored the single-electrode system. Even had this not been the case, the single-electrode system probably would have been chosen because of its apparent advantages in this particular application.

When using a single electrode, the resistance that is logged is a function of the resistivity of the earth material surrounding the electrode. As seen in the wiring diagram in Fig. 1, a number of other resistances are in the circuit. The basic formula for the circuit is:

$$R_f = \frac{e}{I} - \left[r_a + (dr_c + r_x) + r_{ls} + r_g \right]$$

in which

e = oscillator voltage
I = current in the circuit
R_f = resistance of the formation
r_g = resistance of ground
r_{ls} = resistance of line switch
r_a = resistance of apparatus
r_x = depth compensating resistance
r_c = resistance of cable/ft.
d = depth

As the resistance of the cable is proportional to depth, a compensating resistance r_x is introduced into the circuit, and as pipe is added to the string, r_x is adjusted so that

$$dr_c + r_x = \text{Constant}$$

All other resistances appearing on the right-hand side of the equation are constant, or practically so, hence the current I depends only upon R_f. Thus:

$$R_f = \frac{e}{I} - K \text{ (a constant)}$$

and the recording meter, which is primarily a current recorder, is calibrated to read the resistance R_f directly in ohms. This resistance then is characteristic of the formation in the immediate proximity of the bit.

Earth potentials cause direct current to flow in the circuit. Because it is desirable to record both resistance and earth potential simultaneously and because only a single insulated conductor to the electrode is provided, alternating current is used for making the resistance measurements. This permits a

separation of the two in the recording apparatus by means of the filter shown in the diagram. The duplex recorder thereby gives a complete log of both formation potential and formation resistance.

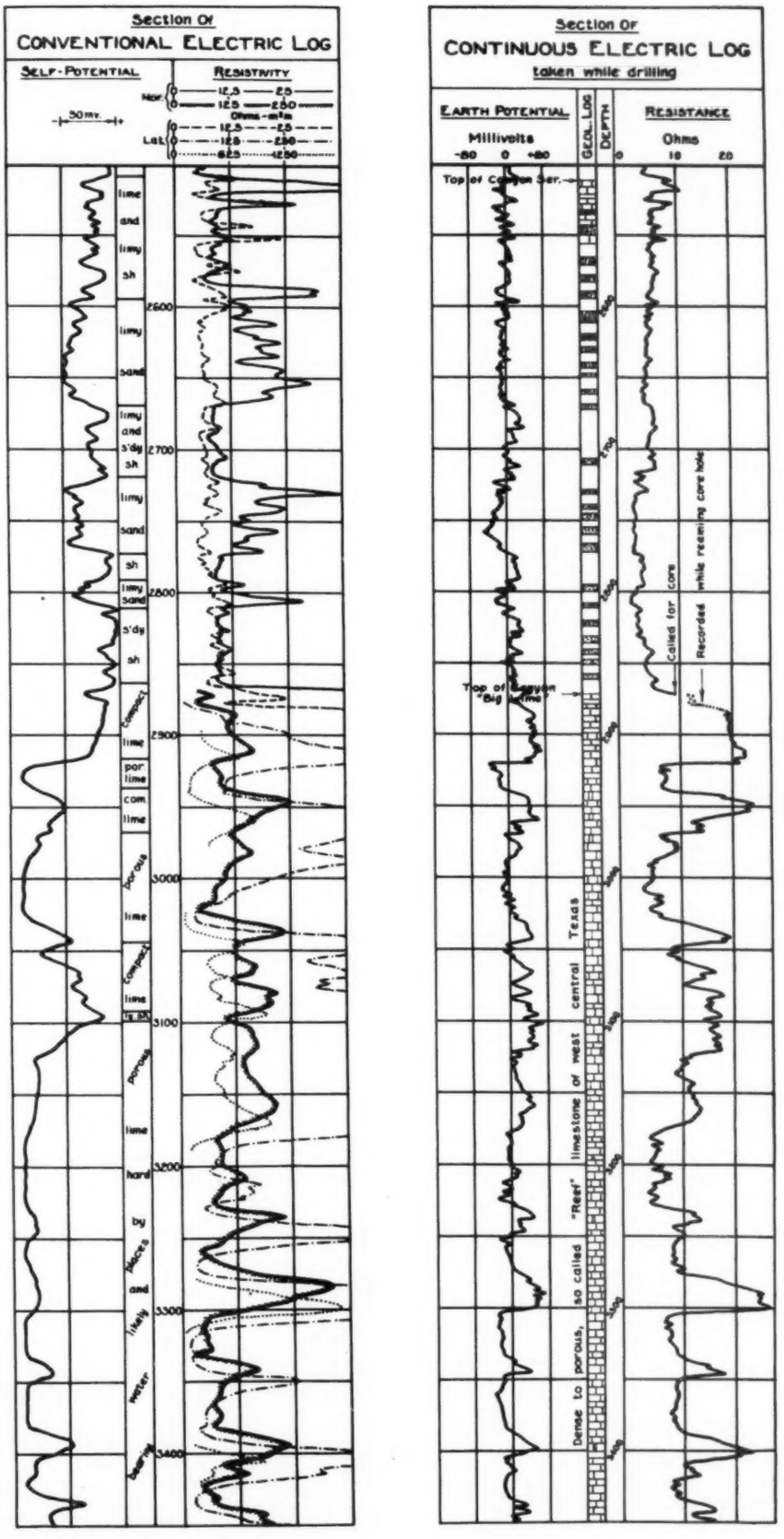
Testing the Circuit

Early in the development the need for means to test the electrical circuit was recognized. This need arose because of the peculiar nature of the mechanical construction of the circuit. Instead of connecting the recording apparatus to the electrode by means of a single length of cable, as is done with other types of electric logging equipment, each joint of pipe was so fabricated that it contained a section of cable having an automatically-engaging terminal at each end. Each pair (male and female) of terminals is required to engage properly and make and maintain good electrical contact and likewise to provide thorough insulation of the conductor. There are two terminals, through which the current must pass, for each pipe connection in the drill string. The failure of any one of these terminals would result in loss of the circuit; hence, the need for a means of testing the circuit is quite obvious.

A special circuit-testing switch called the "line switch" was developed to meet this need. It is mounted in a special sub whose place in the drill string is immediately above the insulated drill collar. It is connected into the circuit as shown schematically in the wiring diagram, Fig. 1. By means of this switch the operator in the trailer can, whenever he desires, test the entire circuit from the recording trailer to the top of the drill collar for "continuity" or for "insulation resistance." These tests are made with no interruption to drilling or loss of record. The line switch contains an actuating solenoid, which is energized from the batteries when S_1 and S_2 are thrown to the right. The rheostat provides an adjustment for the current. Considerably more current is required to actuate the line switch than is used in the recording apparatus. The line switch is so constructed that when S_1 is thrown to the left, turning off the energizing current and bringing the ohmmeter into the circuit, readings of continuity and insulation resistance are successively indicated.

Construction of the Drill Stem

The design and development of the special drill stem involved three major problems. The first was the drill pipe. How and in what manner could an insulated electric conductor be in-



Corresponding sections of two electric logs each taken in the same well—the one on the left was obtained by the conventional method and the one on the right by the continuous system while drilling

corporated integrally within a joint of drill pipe so that current might be carried from one end to the other? The next and probably the most difficult problem of all was to develop means to carry current from one joint of pipe to another and still keep the mechanics practical and applicable to rotary rig practice. The third problem was the design and construction of an insulating drill collar that would insulate suitably the bit from the drill pipe.

The Drill Pipe. A manufacturing procedure was developed whereby a small semi-elliptical, cold-drawn, seamless-steel tube was brazed to the inner periphery of the drill pipe to serve as a conduit. By this means, an electric cable can be protected and securely held to the inside wall of the drill pipe. A section of pipe is illustrated in Fig. 2. The steel conduit tube runs the full length of a joint and is brazed throughout the entire length. A cable can be drawn into the conduit either before or after bucking on tool joints. With the exception of the conduit, the pipe is standard 4½-in., 16.60-lb. A.P.I. drill pipe. The entire fabrication of the drill pipe containing the conduit was done at the pipe mill.

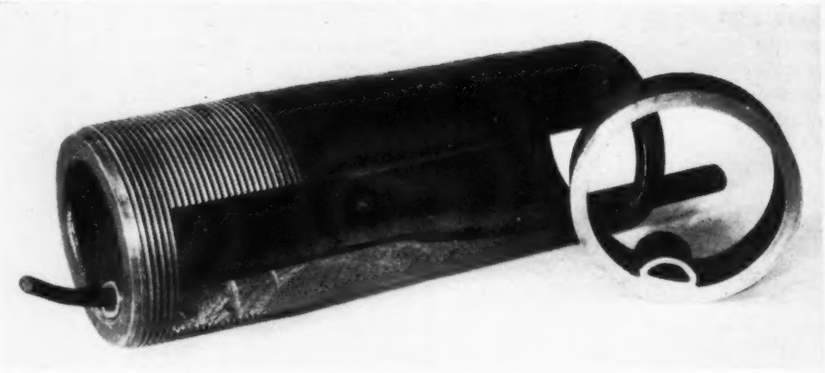
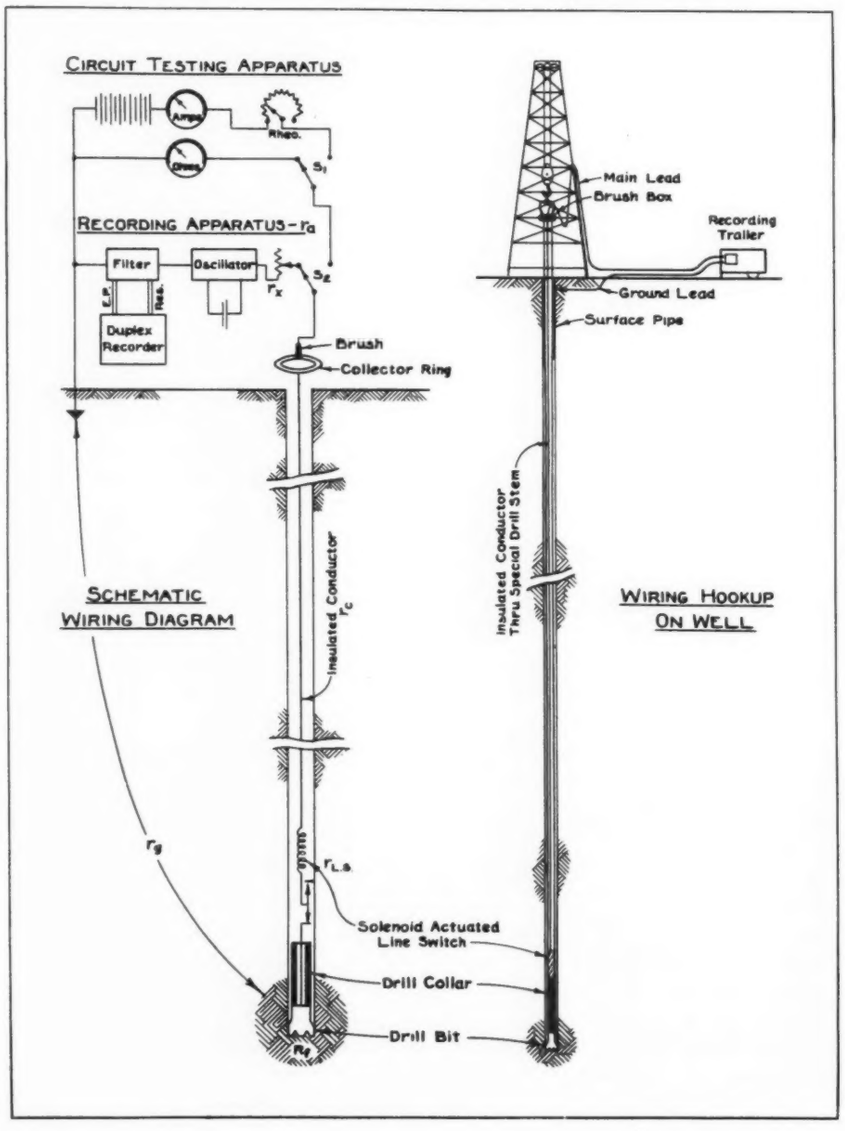


Fig. 2. Section of pipe with conduit brazed in place, and cutaway section through upset showing conduit and cable

Fig. 1. Wiring arrangement of electrical logging apparatus for obtaining while drilling a continuous record of formations penetrated



Brazing the conduit to the inside wall of the drill pipe was done simultaneously with "normalizing." An ordinary manganese bronze containing roughly 60 percent copper and 40 percent zinc was used; its melting point is about 1550°F., or some 50°F. less than the usual normalizing temperature of 1600°F. for the steel of the drill pipe. The bronze was drawn into wire and woven into an eight-mesh screen for the purpose of holding flux. The screen was sheared into strips 1 in. wide by 10 ft. long. After wiring the bronze screen strips to the conduit tube and fluxing, the assembly was slipped into the drill pipe and loaded into the "car bottom" furnace. Ordinary mill practice is to use the continuous sloping hearth furnace for normalizing. This furnace, of course, could not be used, for the pipe must not be rolled while the conduit is being brazed. The continuous furnace, however, subsequently was used for "drawing" the pipe at the lower temperature of about 1200°F.

The physical and mechanical properties of the pipe apparently have been affected in no way by the presence of the conduit. Comparative fatigue tests were made at the pipe mill but no differences from standard drill pipe were observed. Likewise, under actual drilling conditions, nothing has developed that indicates the conduit is detrimental to the life or service of the pipe.

The Insulated Electric Terminals. Special terminals were designed to provide means for conducting current from one section of drill stem

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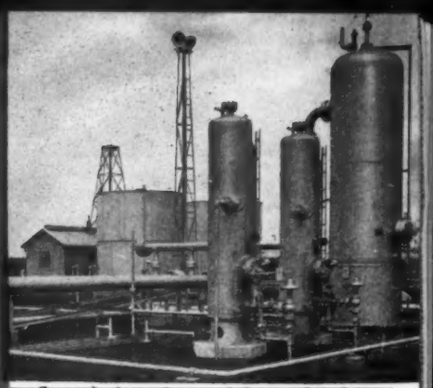

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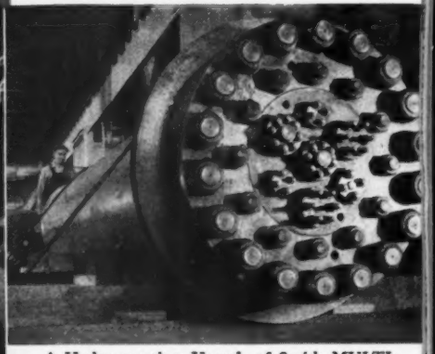

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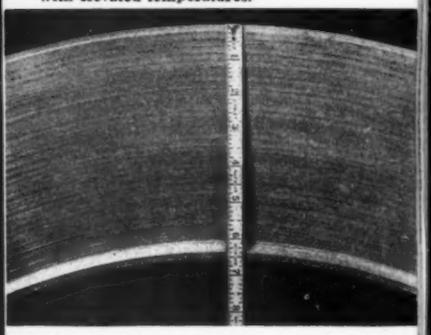

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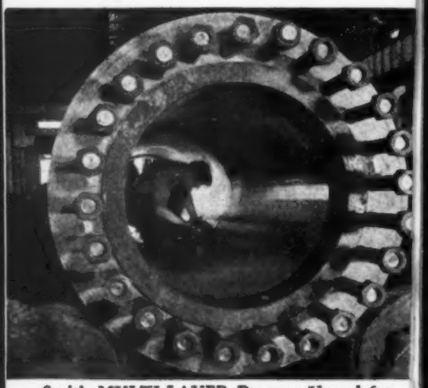

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to another. One terminal is called the male and the other the female. Male terminals are attached to the cable in the drill stem sections and mounted in tool joint "boxes." Female terminals likewise are attached to the opposite end of the cables and mounted in tool joint "pins." When tool joints are screwed together, the two terminals automatically engage to make electrical contact and simultaneously insulate the conductor. An illustration of the assembly is shown in Fig. 3.

The female terminal is made from a short steel annulus or sleeve having a wall thickness of ⅛ in. The sleeve is covered inside and out and around one end by an ⅛-in. thick insulating jacket of neoprene (synthetic oil-resistant rubber). The other end of the sleeve is left exposed to form the contact. At this point, the neoprene is moulded onto the steel in such a manner as to form protruding lips, thereby making a circular trough or groove, at the bottom of which is the contact. An insulated metal finger projects from the covered end of the terminal and is used for attaching the cable. The entire metal section of the terminal is the conductor. When attaching the terminal to the cable, the metal finger is soldered to the copper conductor of the cable. An insulating neoprene jacket is then vulcanized over the joint. Several female terminals already attached to cables are shown in Fig. 4. The spliced joints are soaking in a bath of salt water preparatory to testing the insulation for electrical leakage. Bronze bands used for supporting the neoprene lips may also be seen.

A heat-treated alloy-steel sleeve of the same dimensions as the female annulus only longer, is used in making the male terminal. This sleeve is made into a coil spring by milling-out a spiral slot. The spring is then covered by an ⅛-in. jacket of neoprene, the same as the female terminal. Only the top end of the spring is left exposed to form the contact. The neoprene at this point is moulded to form a wedge or receding lips over which the protruding lips of the female terminal flush, thereby insulating the conductor. The male terminals are attached to the cables in the same manner as the females. Several male terminals ready to be assembled in the tool joint boxes are shown in Fig. 5.

The terminals are mounted in the

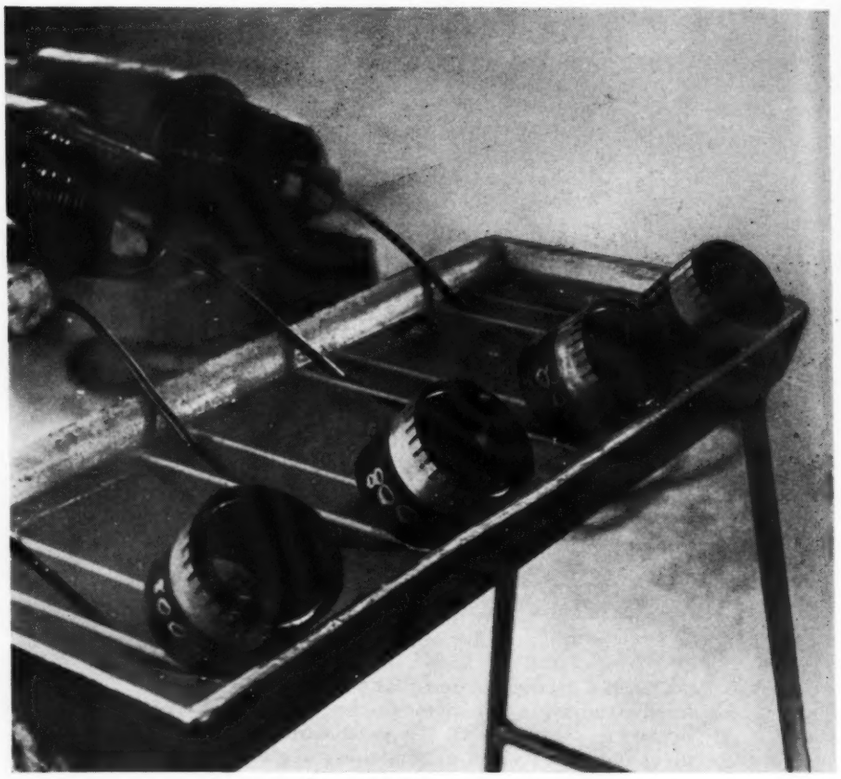
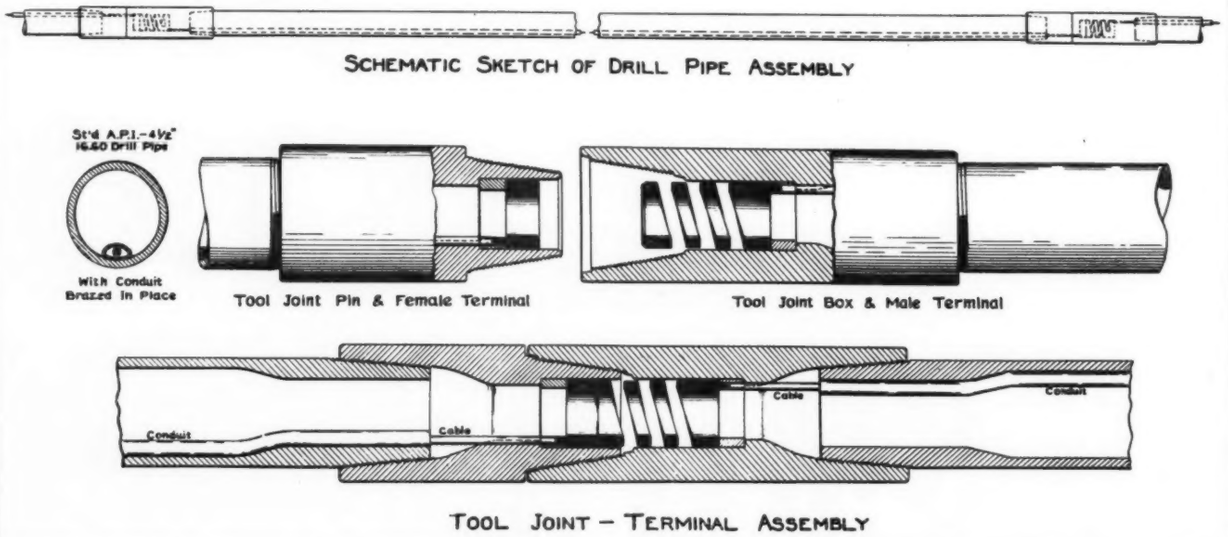


Fig. 4. Showing a group of female terminals and method of testing spliced joint in salt water bath

Fig. 3. Detail of drill pipe and tool-joint terminal assembly



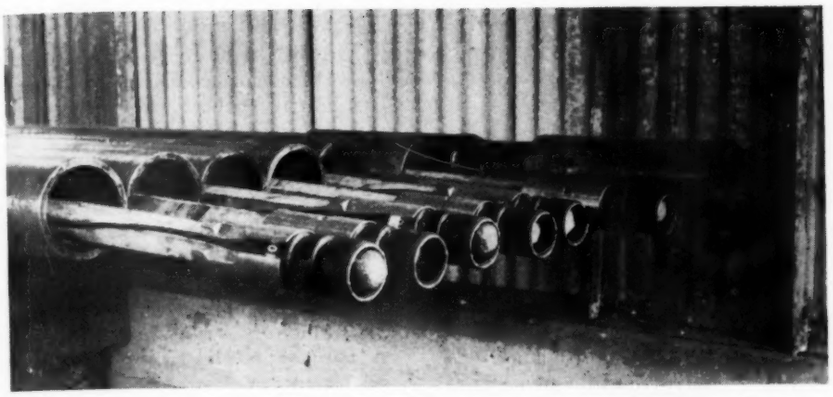


Fig 5. Group of male terminals ready for assembly in tool-joint box—Note contact at end of terminal and the spliced joint in foreground showing where terminal is attached to cable

tool joints so that they engage at the proper time as two sections of drill stem are screwed together. They are spaced to obtain ½ in. to ⅝ in. compression in the spring or male terminal. This results in a compressive force of 100 to 125 lb. per sq. in. Approximately 60 lb. per sq. in. is required to flare the female terminal lips and make contact. The remaining force is utilized to give ample contact pressure to prevent any possibility of vibration during drilling.

The Insulated Drill Collar. For the bit to function as an electrode it must be insulated from the drill pipe. For the two steel members to be separated only by a simple layer of insulation, however, is not enough, as they are both submerged and surrounded by the conductive drilling fluid. To measure properly the resistance desired, it is necessary for most of the current leaving the bit to pass into the surrounding formation. Much loss of current by conductivity through the mud stream to the steel above means loss of sensitivity and inaccuracy in the resistance measurements. Therefore, in addition to insulating the bit from the steel of the drill stem above, it is also necessary to provide a sufficient length of insulating section between the two, so as to make the electrical resistance of the mud path relatively high.

The insulated drill collar is illustrated in Figs. 6 and 7. It is essentially constructed in two parts—the main insulated steel body and the top steel sub. The main steel body of the drill collar, with the exception of the bottom tool-joint box where the bit is screwed, is knurled over its entire outer surface. The short section at the bottom is left exposed for "tong" space, and it, together with the bit, constitutes the electrode. A jacket of canvas-laminated bakelite ¾-in. thick is moulded onto this outer surface. A bakelite tube is mounted in the bore. The two bakelite sections are then joined around the top to insulate the upper end. This, so to speak, places the main steel body in an envelope of insulation. The top end of the bakelite jacket is threaded for 16 in. on a taper of 1 in. per ft., with sharp "V" threads of 8-pitch. The top steel sub is made to screw onto these bakelite threads, which must be able to withstand all the strains of drilling, just as any other threaded joint in the drill stem. The top sub is screwed on very tightly at the mill and is never taken off in the field. The upper end of the top sub is a tool-joint box, in which a male terminal is mounted and properly connected and insulated by a lead running to the top end of the main steel body. The main body serves as the conductor the rest of the way to the bit.

The steel of the top sub is separated from the steel of the electrode by an insulating section 10 ft. long. This is amply sufficient to obtain correct resistance measurements even when the resistivity of the drilling mud becomes quite low. While drilling, this outer 10 ft. of bakelite jacket is exposed and is subject to wear against the walls of the hole. In the course of drilling the six test wells, the two drill collars originally constructed have each been covered three times. A record of these bakelite jackets in service is shown in Table 2. Five bakelite jackets have been used, but two of them have not been completely worn out. By estimating a correction factor and adjusting, a figure of about 7500 ft. of hole per jacket is obtained. This figure is quite satisfactory and with time and experience it may be reasonably expected to be improved upon.

The Kelly and Kelly Subs. To complete the drill stem it was neces-

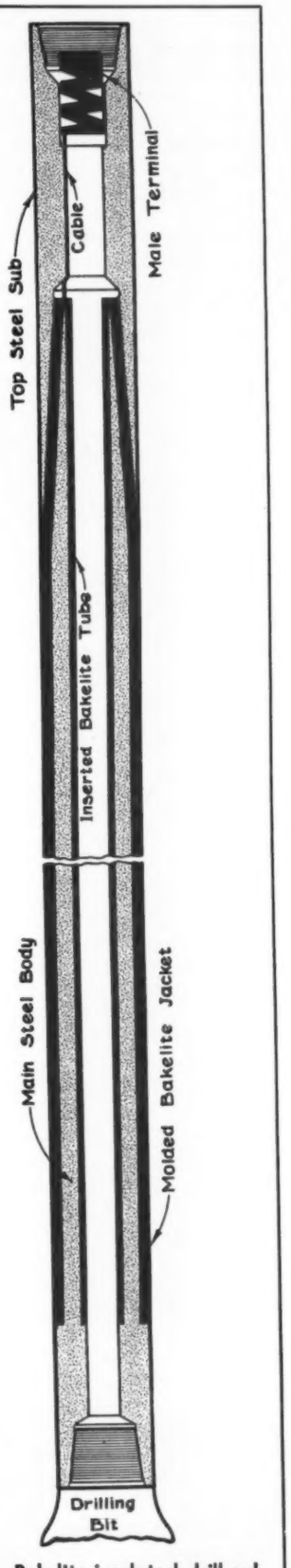


Fig. 6. Bakelite-insulated drill collar—7 in. O.D. by 14 ft. long and 10 ft. of exposed bakelite-insulated section

sary to construct a special kelly and special kelly subs. A small circular tube was welded into the outer surface of a square kelly to form a conduit for holding a length of cable. At the upper end the cable comes out into the open where it can be attached to the brush box. At the lower end the cable passes through a stuffing box into the inside of the drill stem where it is connected to a terminal. Two kelly subs were made, each being equipped with a pair of terminals and a short length of cable for connecting them together. Provisions were made for protecting the cable and holding it out of the mud stream.

Miscellaneous Equipment. A brush box was made to mount on the kelly immediately below the swivel. It may be seen in Fig. 7. The brush box is a unitized assembly containing a collector ring and a set of brushes. The main lead of the recording circuit comes from the trailer to the derrick, runs up the standpipe, is taped to the rotary hose, and extends across the swivel and into the brush box. Here it connects to the brushes. The section of the brush box upon which the brushes are mounted is kept from rotating by arms projecting downward from the swivel. The collector ring rotates with the main body of the brush box and is connected to the main circuit lead from the kelly.

It is necessary to provide means for driving the recording meter chart and for keeping it in step with the downward progress of the bit. Autosyn motors are used for this purpose. The transmitter motor is fixed to the end of the drawworks drumshaft and is rotated as the pipe is raised and lowered. The autosyn receiver is attached to the chart mechanism of the recording meter in the trailer. This serves to drive the chart in synchronism with the advance of the bit as the hole is drilled. Means are supplied for calibrating the motion, to provide for different sizes of drums and different sizes and spoolings of the drilling cable. For operation by the driller, a switch is provided that controls the motors. By turning the motors on and off at the proper time when making a connection the chart is kept continuously in proper footage relationship to the depth of the hole.

Autosyn motors require alternating current. As this is not usually available around rotary rigs, a small 300-watt gasoline engine generator is used to supply the current. Two of these generators are kept with the equipment in order to have a standby in case one fails.

An instrument and control panel

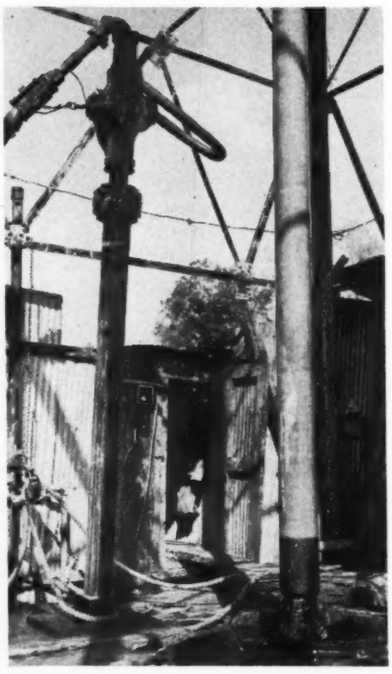


Fig. 7. Brush box mounted on kelly just below swivel. Bakelite-insulated drill collar on right with bit attached ready to run in hole. Testing panel and telephone are mounted on wall of house just to right of kelly joint

are in the recording trailer, and testing and operating panels on the derrick floor. Signal lights at both places indicate to the operator and to the driller correct or incorrect functioning of the several parts of the equipment. Master controls for the main circuit and for the recording and testing apparatus are in the trailer.

Conclusions

The drill stem and equipment that have been constructed have proved particularly applicable to drilling and to rotary rig operations. During drilling of the first few wells, considerable trouble was experienced with the equipment. This caused a material increase in drilling time. The source of the trouble was later found and the trouble corrected. Drilling time is now affected in an almost negligible degree. The equipment has given good service. A few repairs and replacements have been made, but for the most part the equipment appears to be little affected by the demands of service it has thus far met. It is reasonable to expect that the life of the special drill stem with its electrical assembly will equal that of standard drill pipe.

Electrical logging while drilling appears to have several definite advantages. Some are quite tangible whereas others are intangible. All apply more or less to the drilling of wildcat wells and also to the drilling of proven structures that are unusually difficult to explore. Among the most important advantages of continuous electrical logging are: it is an invaluable aid in conducting an intelligent coring program; contact points and breaks in the formation can be instantly detected as the bit drills by; data that indicate the nature and characteristics of the formation being drilled, are continuously and instantly available for subsurface correlation while drilling is in progress. The availability of this information, coming to hand immediately and continuously, should be of great assistance in answering the many difficult questions arising in present-day deep exploratory well drilling.

TABLE 2
Insulated Drill Collar Service Record

Drill Collar	Bakelite Jacket No.	Well	Drilled From ft.	Drilled To ft.	Drilled Total ft.	Est. percent worn out	Adjusted footage	Remarks
"A"	1	No. 2 Smith	1242	5155	3913			Gulf Coast (soft)
		No. 1 Emmott	1208	5203	3995			Gulf Coast (soft)
		No. 1 Silberberg	1213	4467	3254			Gulf Coast (soft)
					11,162	100	11,162	
	2	No. 1 Kleiner	4468	5607	1139*	50	2,278	North Central Texas (hard-chert)
	3	No. 10 Berk	80	4025	3945†	30	13,150	East Texas (soft)
"B"	1	No. 2 Knight	287	4977	4690			Central Oklahoma (hard)
		No. 2 Smith	77	1242	1165			Gulf Coast (soft)
					5,855	100	5,855	
	2	No. 4 Silberberg	4467	5412	945			Gulf Coast (soft)
		No. 1 Kleiner	247	4468	4221			North Central Texas (hard-chert)
					5,166	100	5,166	
	3	New			none			
			Adjusted Average				7,522	

*Discarded prematurely.
†Still serviceable.
Note—On each original drill collar the insulation covering was renewed three times.

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the mud valve with a renewable resilient flow-way insert . . . Saves 93% maintenance!

1. Forged steel throughout; heat-treated alloy steel gate.
2. All parts subjected to wear are of heat-treated alloy steel.
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4. No metal-to-metal seal. Resilient insert provides pressure-tight seat for gate, readily embedding cuttings or other foreign matter.
5. Interlocking shoulders and grooves between body and hubs permit valve to swivel like a union when making up in a manifold.
6. Body may be quickly fitted with flanged, threaded, welded-on, or any special hubs desired.
7. Indicating stem shows position of gate at all times.
8. Available in 2", 3", and 4" sizes, 6,000 lbs. test pressure.

*2" size, $5.50; 4" size, $9.50.

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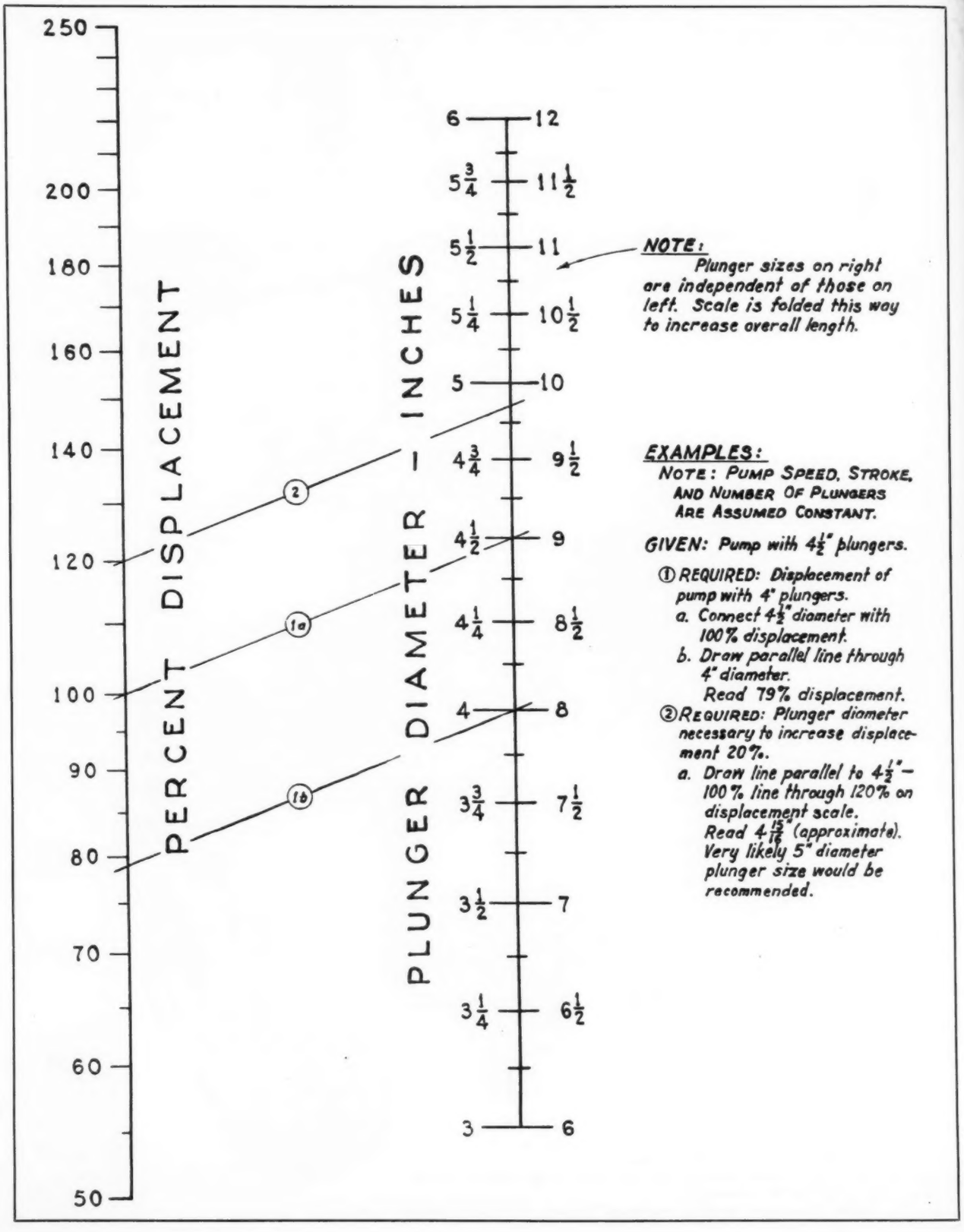
P 069.
P 094.86

Alignment Chart for Determining Pump Displacements as Related to Plunger Diameters

By FRANK E. HANGS



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▼ Perfectly straight rods—quenched by clamping in water-cooled dies—are produced in the D + B heat-treating furnace. Straightening and stretching devices are eliminated.

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CHEMICAL	
Carbon	.07/.11
Manganese	.20/.50
Phosphorus	.025 Max.
Sulphur	.030 Max.
Silicon	.15/.30
Nickel	3.00/3.50
Copper	1.45/1.65
PHYSICAL	
Yield	85,000/95,000
Tensile	95,000/105,000
Elongation (2")	40 Average
Reduction of Area	62 Average
Impact: Izod	90/105
Charpy	45/55
Brinell	207 Average

CONTINENTAL

SERVING THE OIL AND GAS INDUSTRIES

Construction Features of High-Pressure Absorption-Type Natural Gasoline Plant

Plant in Bistineau field, Louisiana, supplied by gas-distillate wells, has capacity of 25,000,000 to 30,000,000 cu. ft. of gas per day

By D. H. HUFF, Plant Superintendent, and DON ATTAWAY, Arkansas Fuel Oil Company

ON December 1 the Arkansas Fuel Oil Company placed in operation its Bistineau gasoline plant. The plant site is on a ten-acre tract of the Sam Carter farm and is approximately 8 miles north of Ringgold, Louisiana. Only one-half mile away is Lake Bistineau, a famous fishing grounds for sportsmen of the Arkansas-Louisiana-Texas area.

Construction of the plant began October 5, and due to unusually fine weather, progress was rapid. One of the first problems facing the company's engineering personnel was the high pressure at which it was necessary to operate the plant. A second problem was to find a practical method of handling the gas and liquid produced by the six gas-distillate wells feeding the plant. One of these wells has an open flow of approximately 150,000,000 cu. ft. per day.

The main gathering line is a 10-in. welded line and upon arrival of the gas and liquid at the plant a separation is effected by two high-pressure separators. Inlet gas pressure is regulated and controlled by equipment designed for 1000-lb. pressure.

The plant proper is of the conventional absorption type and two 4½-ft. by 44-ft. vertical high-pressure absorbers treat the gas after it has been measured by three 8-in. meters. The gas is discharged through three 8-in. outlet meter runs laid parallel to the inlet meters. Back-pressure equipment is installed on the outlet meter runs to maintain 450-lb. operating pressure. Gas is delivered into the 14-in. main line of the Arkansas Louisiana Gas Company for domestic and commercial distribution.

Rich oil from the high-pressure absorbers is trapped into a surge tank that also receives the distillate trapped from the inlet separators. This enriched oil is passed through a steam distillation unit and the overhead vapors condensed by two atmospheric-type condensers installed in the base of the cooling tower. Gasoline produced here is accumulated in a 6-ft. by 12-ft. horizontal vessel that also serves as a raw charge tank for the stabilizer.

After being stripped in the steam still, the lean oil is trapped into a horizontal direct-fired preheater and charged to a 36-in. by 30-ft. naphtha still. A novel arrangement of controls on the naphtha still governs the speed of a turbine-driven centrifugal pump that takes oil from the steam still exchanger and discharges it through an initial cooler, thence to an atmospheric-type cooler in the base of the cooling tower.

The overhead from the naphtha still passes through a conventional water-cooled condenser and into the accumulator. A duo-gravity trap on this accumulator discards the water and the finished naphtha is delivered to a 10-ft. by 40-ft. storage tank.

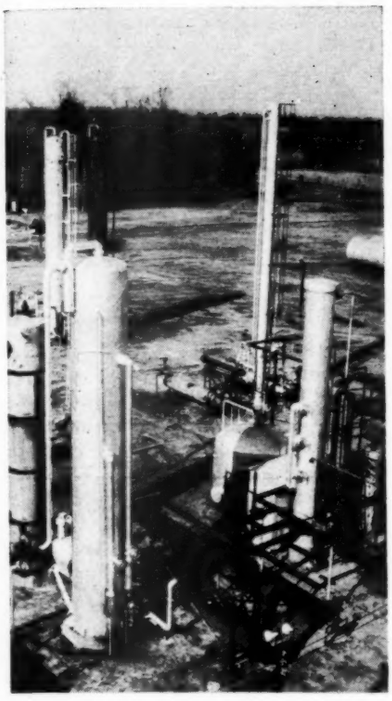
An interesting sidelight is that throughout the entire flow system to this point not a single pump is required except to pump the lean oil through the cooler. Full advantage was taken in design to utilize pressures as a prime motive power. Likewise the vapor recovery is almost complete,

D. H. HUFF

graduated from Texas A. and M. College in 1933—Entered the service of the Arkansas Natural Gas Corporation in 1933—Served as chemical engineer at East Texas gasoline plant until September, 1935—Accepted a position in the company's engineering department and remained until February, 1937—Returned to the East Texas plant as plant engineer and remained there until July, 1938—Promoted to superintendent of Rodessa gasoline plant and in October, 1939, was appointed superintendent of the Bistineau plant.

DON ATTAWAY

began his career in the oil industry with the Dixie Gulf Gas Company as timekeeper in the Waskom district, January, 1928—Entered the payroll department of United Gas Company late in 1929 and worked there until he accepted a position with Arkansas Fuel Oil Company in September, 1930, in the gas accounting department—Worked successively as meter man, loading rack man, and utility man in the East Texas natural gasoline plant—Took an active part in the construction and operation of the Jefferson, Sligo, and Shreveport gasoline plants of the company.



Overhead view of the gasoline and naphtha distillation units; absorbers in far background, and stabilizer in middle background

even the boilers being fired with fuel from the rich-oil tank vapors.

The stabilizer is a 18-in. by 56-ft. unit of customary design and at present is manufacturing an 18-lb. Reid vapor pressure product that is delivered into three 10-ft. by 40-ft. storage tanks.

Steam for plant power is generated by four 115-hp. oil-field type boilers operating at 150-lb. pressure. These boilers are equipped with automatic feed-water regulators and boiler-fuel controls. Two 7½ by 5 by 6 reciprocating pumps pump the boiler-feed water, which is preheated in an unusual heater designed from a reclaimed cheese-box still. All turbine exhausts discharge into a return steam line that feeds the heater and a cold water make-up line passes through a steam heater.

Water for plant use is obtained from two water wells drilled approximately 200 ft. deep. Gas-lift delivers the water to a separator on the west side of the cooling tower.

The cooling tower is of unusual design and arrangement, having both a hot and cold water section in its basin. A dividing wall is in the center of the tower and on one side the water falls through the tower and over an oil cooler and two gasoline condensers, making a reservoir of hot water in this end of the basin. Through the other side of the tower cold water falls into the basin and is picked up by a 10 by 12 reciprocating pump and circulated to the still and stabilizer condensers. This water returns through a riser to the top of the cooling tower. Two turbine-driven centrifugal pumps having a capacity of 600 gal. per min. pick up hot water from the other basin and discharge it into this same riser.

Lighting for the plant is produced by a 35-hp. turbine driving a 15-kw., 115-volt d-c. generator and modern floodlights are strategically placed to illuminate each individual unit.

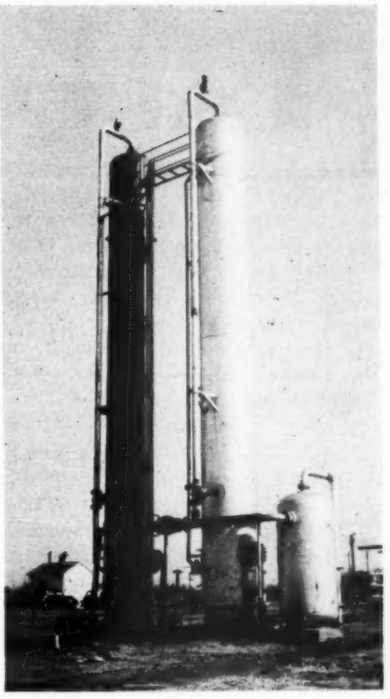
The plant is very compactly arranged. The pumping equipment has been centrally placed in one unit and convenient standby connections are provided. Adequate consideration has been given to future expansion, and repairs or future extension of any unit may be made without the customary complete shut-down.

The plant's gasoline production is pumped by a 10 by 6 by 12 reciprocating pump through 3½ miles of 2-in. welded line to a five-car loading rack constructed on the S. L. B. & S. railway. By blending naphtha and natural gasoline at the plant, an excellent motor fuel is produced that is moved by tank truck from the plant to the rack where it is loaded and shipped. Due to the quantity of fluid received at the plant along with the gas, a surplus of absorption oil is available after the usual stripping and this, too, is shipped by tank truck.

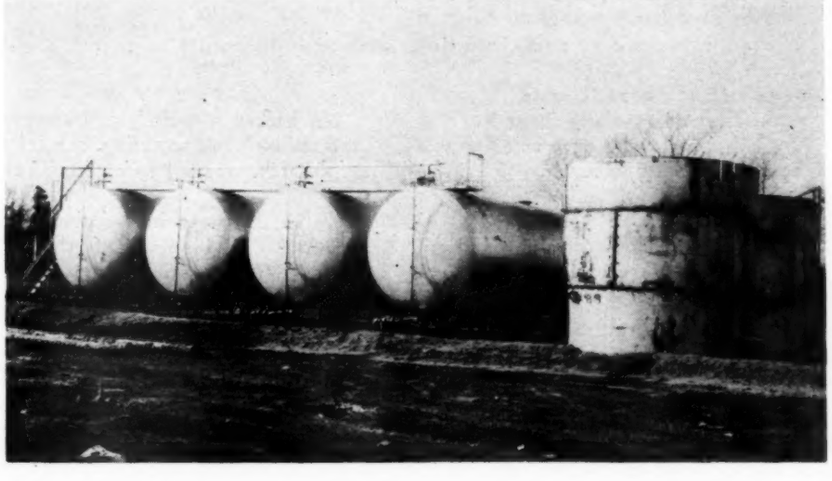
The entire plant is equipped with modern recording-controlling devices and all safety features possible have been incorporated in the construction. Latest fire-fighting equipment is placed at strategic points. At the present time 25,000,000 to 30,000,000 cu. ft. of gas per day is being treated and a yield of 275 to 300 gal. per million is obtained.

A credit to the engineering department of the Arkansas Fuel Oil Company is the fact that this plant was constructed without a single lost-time accident and only two minor injuries were sustained by workmen.

Pictures of the plant shown herewith were taken before the construction was entirely completed or any of the units painted in the customary aluminum and black color scheme of the company. It is believed that after the usual landscaping and paving, the plant will be one of the company's most attractive properties.



Absorber battery and outlet scrubber



Battery of storage tanks

LAUGH WITH BARNEY

A burly new chief of police, introducing himself to his subordinates, boasted, "I can lick anybody on my force." A still burlier officer stepped forward and said, "You can't lick me." The chief eyed him for a moment, and then waved him aside, "You are no longer on my force."

* * *

Neighborhood Gossip: And your husband has a prosperous business, I suppose.

Mrs. Newbride: Oh, yes, he is taking in a lot of money. Only last night he told me a receiver was to be appointed to help him.

* * *

"What happens to the girls who wear cotton stockings?"

"Nothing."

* * *

Rastus: Say, Sambo, what time in yo' life does yo' think yo' was scared de worst?

Sambo: Once when Ah wuz callin' on a henhouse an' de farmer come in an' ketched me. Boy wuz Ah scared.

Rastus: How am yo' suah dat was de worstest yo' evah bin scared?

Sambo: Cause de farmer grab me by de shoulder an' he say, "White boy, what yo' doin' here?"

* * *

In Atlanta it wuz Mabel,
In Mobile her name wuz Flo,
Cincinnati it wuz Dolly,
Betty Jane in Buffalo.
In old Philly it wuz Mary,
Down in Tampa it wuz Jean,
But on the w.k. swindle sheet
It wuz "Meals an' Gasoleen."

* * *

Mountaineer's wife: "Quit bein' so nervous and fidgety, Paw, you're pullin' yore shoes up over your knees."

* * *

Office Manager (to new office boy): Has the stenographer told you what to do in the afternoon?

New Boy: Yes, sir; I was to wake her up when I saw you coming.

* * *

An angler who had been trying to hook something for several hours was sitting gloomily at his task when a mother and her small son came along. "Oh", cried the boy, "let me see you catch a fish!" Addressing the angler, the mother said severely, "Now, don't catch a fish for him until he says 'Please'!"

The flapper had brought out her last winter's fur coat and was gazing at it disconsolately, surveying the big gashes in the lining, and the other places in need of repairs.

"Gosh, wonder what I'll have to do for this fur coat?" she remarked to her roommate.

"Holy Moses!" gasped the other, "ain't you done it yet?"

EXPENSE REPORT

Month Ending — October 31, 1939

Date		*Amount*
Oct. 1	Advertising for girl stenographer	$ .50
Oct. 2	Violets—new steno	.65
Oct. 8	Week's salary for stenographer	15.00
Oct. 9	Roses for stenographer	3.00
Oct. 11	Candy for wife	.75
Oct. 13	Lunch with stenographer	6.25
Oct. 15	Week's salary for stenographer	20.00
Oct. 17	Movie—self and wife	.80
Oct. 18	Theatre tickets—self and steno	7.50
Oct. 19	Candy for wife	.75
Oct. 20	Stenographer's salary	25.00
Oct. 21	Theatre and dinner with stenographer	21.75
Oct. 22	Fur coat for wife	625.00
Oct. 23	Advertising for man steno	.50

A missionary society member approached Henry, "We are having a raffle for a poor widow," she said. "Will you buy a ticket?"

"Nope," said Henry. "My wife wouldn't let me keep her if I won."

* * *

A salesman called on an old storekeeper who was so hard of hearing the salesman had to carry on his part of the conversation through writing.

Salesman: Sorry you're so hard of hearing. How long have you been that way?

Old Man: About 30 years.

S.: Ever do anything about it?

O.M.: Yes, saw a doctor and he said to quit drinking so much.

S.: And did you follow the doctor's advice?

O.M.: Yes, I quit drinking and got so I could hear everything that was going on.

S.: How come then you can't hear now?

O.M.: Well, I liked what I was drinking so much better than what I was hearing that I went back to drinking again.

Judge: The jury having acquitted you on the charge of bigamy, you are free to leave the court and go home."

Prisoner: Thank you, your Honor, but I want to be on the safe side—which home?"

* * *

The men's class sat up when the following announcement was made by the pastor: "The ladies of this church have cast off clothing of all kinds. They may be seen in the basement of the church any afternoon this week."

* * *

The chief engineer and the master mechanic had spent the evening together. For obvious reasons, the M.M. was a little hesitant about going home.

"I'll tell you what to do if you don't want to disturb your wife," said the chief.

"When you get in the house, undress at the foot of the stairs, fold your clothes neatly, then creep quietly up the steps to your own room."

They met the next morning at the plant. "How did you get on?" asked the chief.

"Rotten," said the M.M. "I did just as you told me. I undressed at the foot of the stairs. I folded my clothes neatly. I crept quietly up the stairs. But when I reached the top—it was the elevated station!"

* * *

Our advice on buying just now is like that of the Wisconsin expert who, after careful deliberation, wired his firm: "Some think it will go up and some think it will go down. I do, too. Act at once."

* * *

"Hi say, 'arry, have yer got any lices?"

" 'Ead lices?"

"No, shoe lices!"

* * *

The barber was dark and swarthy, his eyes black and sparkling. It was evident that he was descended from Latin stock.

"What do you think of the Italian situation?" he inquired of the customer. "What is your opinion of Mussolini?"

"The same as yours," replied the man in the chair.

"But how do you know my opinion?" inquired the startled barber.

"I don't," admitted the man, "but you have the razor."

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. . . never lets you down — not even during a blizzard. The temperature may be zero or lower, but *Electric Power* is right there to serve you the instant you push the switch.

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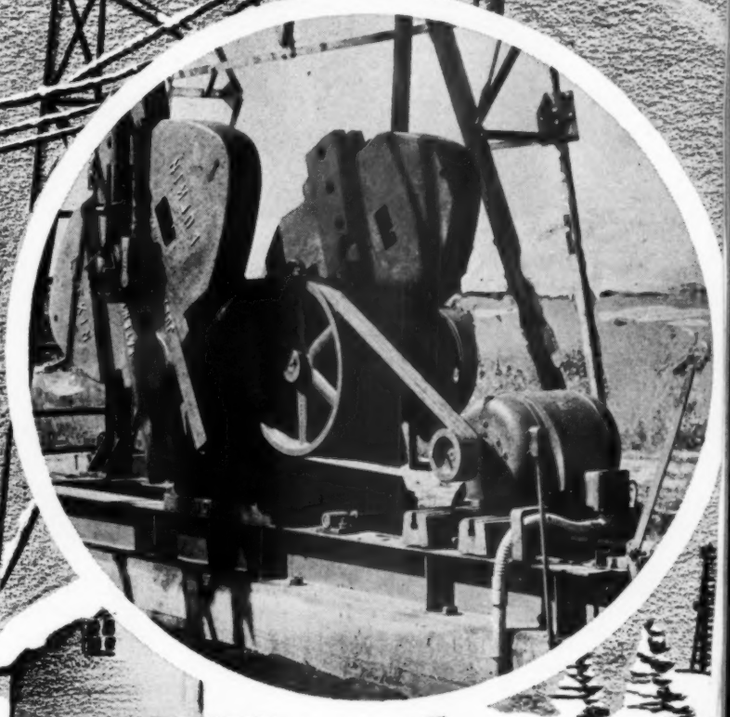
Your nearest Electric Power Company will gladly show you how Purchased Electric Power can increase your profits. Ask them for facts concerning your power problems — today!



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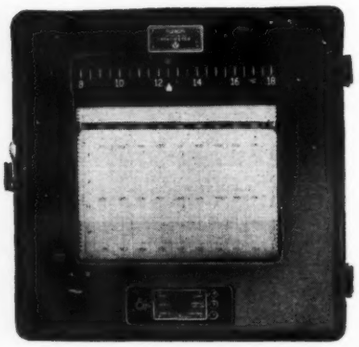
PETROLEUM ELECTRIC POWER ASSOCIATION

MACHINERY and EQUIPMENT

Foxboro Air-Operated Potentiometer Recording Controller

A NEW series of potentiometer recording controllers has been announced by The Foxboro Company, Foxboro, Massachusetts, incorporating three features said by the manufacturer to be unique in instruments of this kind. These features are (1) an improved detecting mechanism, (2) a new integral recording and control mechanism, and (3) a new control



system to provide maximum flexibility of use. Open-and-shut action or throttling action, with or without automatic reset, is available in the air-operated models of the new series of controllers.

In order to obtain a more sensitive detecting mechanism than that required for recording (a requisite for good control action), a single, calibrated detecting cam is used. This cam will sense deflections of the galvanometer pointer of less than 0.0001 in. without lost motion. By positioning a friction roller, the cam positively determines the movement of the integral slide-wire contact, recording and control actuating carriage, it is stated.

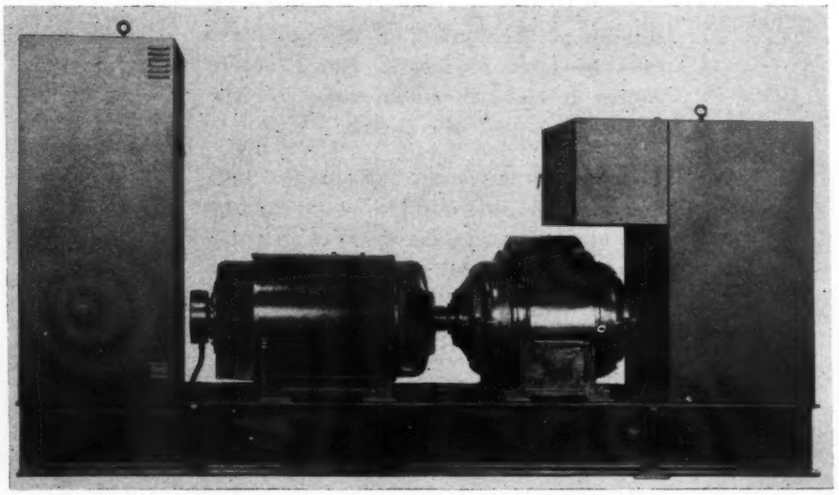
Coördination of measuring, recording, and controlling operations is achieved by an integral recording and control mechanism. The slide-wire contact, recording pen, and cam follower actuating the control cam are assembled as a unit on the same rigid carriage. By employing an integral mechanism, the need for linkages, belts or gears to transmit the position of one unit to the others is eliminated. Guaranteed accuracy is ¼ of 1 percent of scale range.

The control system is affixed directly to the shaft of the cylindrical control cam; the resultant compact, self-contained unit requires no linkages. The rotary motion of the control-camshaft makes for extreme simplicity in providing for the type of control required by application conditions.

The new controller is highly accessible—the entire mechanism can be pulled forward out of the case and every moving part can be removed or replaced by an inexperienced operator standing squarely in front of the case. In addition to this advantage, this construction allows the use of anti-vibration rubber-cushioned mountings within the case, assuring good performance under all industrial conditions, the manufacturer asserts. Routine adjustments for standardizing the circuit are made without opening the door.

For further information address The Foxboro Company, Foxboro, Massachusetts.

G-E Multiple-Operator Welding Sets

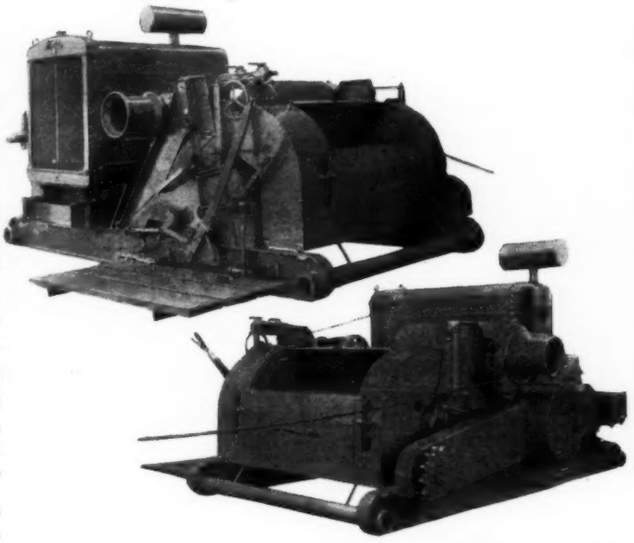


REDESIGN of General Electric Company's 1500-amp. constant-potential arc-welding sets for multiple-operator and machine welding has resulted in more compact construction, lighter weight, improved appearance, and greater ease of installation, the makers state. In addition, the improved equipment has the control for the motor and generator mounted on the base, making for greater convenience for the operator.

Constant-potential motor-generator arc-welding sets are especially suited for supplying the heavy current demands of modern automatic welding and the exacting requirements of production hand-welding by a number of operators, it is asserted. When a number of operators are to be supplied from one set, advantage can be taken of the fact that the average hand-welding operation is not continuous. This diversity factor of the welding load allows the use of a smaller-capacity set in supplying a given connected load than would be required if each operator were supplied by a separate set, and because one large machine supplying a number of welding stations can operate at all times near its most efficient load point.

The sets are equipped with standard driving motors for operation on direct current, or on polyphase alternating current at any commercial voltage. Synchronous driving motors may be used to obtain plant power-factor improvement. This often results in materially reduced power bills.

Cardwell Model L Drawworks



THE Cardwell Manufacturing Company, Wichita, Kansas, announces an addition to its line, a Model L slim-hole or workover drawworks developed especially for slim-hole drilling and workover jobs. This new, lightweight drawworks, driving from a hydraulic transmission through a "Cardwell Speed Drive," operates like a steam rig. The entire range of engine power is constantly available at maximum speed without shifting gears.

The hydraulic transmission sprocket drives to an auxiliary shaft on which three "Cardwell" built friction clutches are mounted. The "Hi-Lo" drive, consisting of two of these clutches with sprockets driving to the countershaft, makes it possible to instantly double the line speed. The third friction clutch operates the rotary table drive and is supplied with clutch brake for stopping the table.

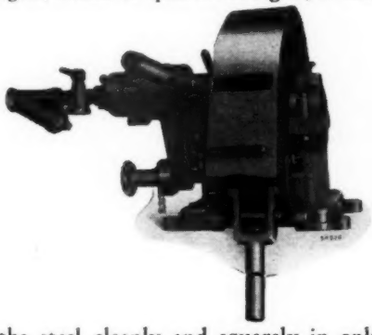
Air controls operate the two "Hi-Lo" friction clutches, rotary table drive friction clutch, and the countershaft brake.

Either of the new, dual, fully-equalized, single-adjustment brakes will automatically hold the full capacity load should the other brake fail, it is stated.

Model L drawworks is for rotary drilling to a depth of 4500 ft. using 3½-in. drill pipe or to 3500 ft. using 4½-in. drill pipe, and for workover jobs to 8000 ft., using 2½-in. tubing.

Drill Steel Cutter and Shank Grinder

INGERSOLL-RAND Company announces a new, Size 500, combination drill steel cutter and shank grinder. Designed for solid or hollow steels to and including 1¼-in. hexagon, round or quarter octagon, it cuts



the steel cleanly and squarely in only a few seconds without burning, the makers assert. A quick-acting, self-locking vise holds the steel rigidly on both sides of the cut.

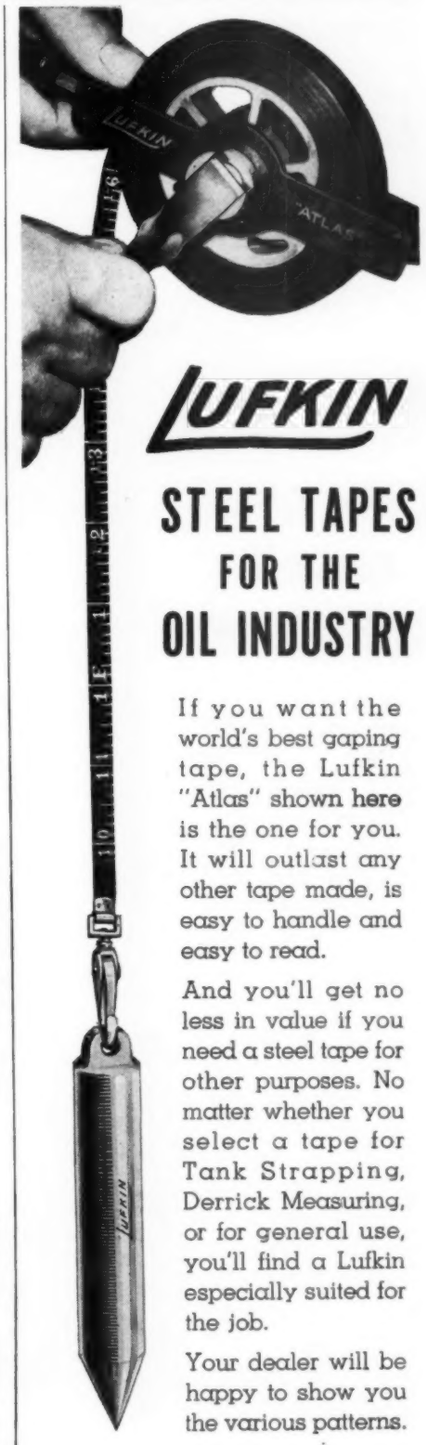
The unit can be readily changed from a cut-off machine into a shank grinder by removing the cut-off wheel and substituting a grinding wheel. As a grinder it can be used for squaring-up striking faces of the shanks of drill steel, moil points, chisels, and the striking end of rock-drill pistons.

For further details address communications to Ingersoll-Rand Company, 11 Broadway, New York City.

Reversible Ratchet

ARMSTRONG Bros. Tool Company, 331 North Francisco Avenue, Chicago, Illinois, announces a new miniature reversible ratchet and

four new drivers for its miniature detachable head wrenches. The reversible ratchet, which is only 4 in. long, is machined from special chrome-vanadium steel finished in chrome plate. The ratchet is of improved design having hardened gear and instant reversing thumb switch. The four miniature drivers added to this series are: Flexible head handle, a screw-driven type extension spin-grip that permits locking head so that it can be used also as a spinning extension, and long and short extensions.



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And you'll get no less in value if you need a steel tape for other purposes. No matter whether you select a tape for Tank Strapping, Derrick Measuring, or for general use, you'll find a Lufkin especially suited for the job.

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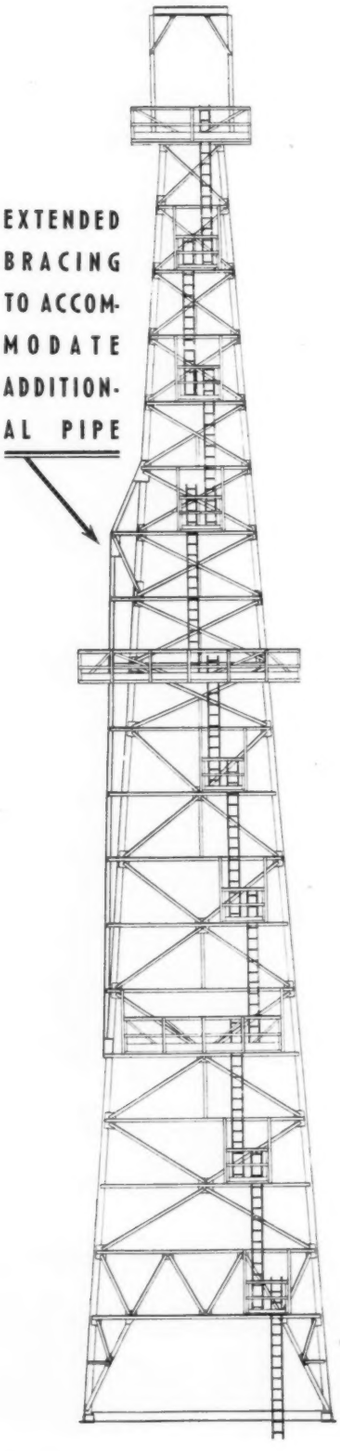
Derrick Permits Racking of More Pipe

IN THE latest designed Type "R" Emsco steel derrick, optional side elevation of which is shown here, the manufacturer asserts a further improvement over previous types designed to provide greater pipe-racking capacity without resorting to higher derricks.

This increased racking area is made possible in the Type "R" by means of an optional special set-back extension outside the derrick legs, as illustrated in detail by Fig. 1; and is accomplished without sacrificing strength, rigidity, or the high factor of safety essential in modern deep-drilling procedure, according to the manufacturer. In all other respects the derrick is standard, having standard base and crowns; permitting the use of standard construction procedure, standard sub-structures, and standard equipment throughout.

Fig. 1



The patented extension permits racking from 33⅓ to 50 percent more pipe than is possible in a conventional derrick, it is stated, as shown by Fig. 2. It can be provided for derricks of any size.

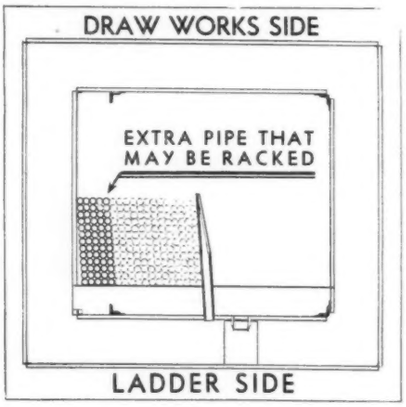


Fig. 2

According to the manufacturer, the Type "R" is the result of continued deeper-drilling practices, with the resulting longer strings, larger and heavier equipment throughout the derrick, all of which have reduced the available space in standard rigs very materially. The company has been perfecting and field-proving the special set-back extension for several years, and it is now available for the Type "R" Derrick as optional in all sizes and capacities. Complete details may be obtained by communicating with Emsco Derrick and Equipment Company, Los Angeles, California; Houston or Dallas, Texas.

United Supply Adds Two Pumping Units

THE United Supply and Manufacturing Company, Tulsa, Oklahoma, has added to its line two new oil-well pumping units. These two units are listed as TD5S and TD20S. The TD5S has a 5.4 A.P.I. nominal hp. rating at 20 s.p.m.; 26,500 in-lb. A.P.I. peak torque; twin-crank, double-reduction, herringbone continuous-tooth gears; 18-in. to 24-in. polished-rod stroke; 6450 lb. A.P.I. walking beam capacity. Counterbalance is optional, and can be had in the beam or rotary type or a combination of both. Counterbalance weights are of approximately 100 lb. each, and can be easily added. The units have fully equalized pitmans. Wristpin is equipped with Shaffer self-aligning roller bearings. The oil-bath center and equalizer bearings are of S.A.E. 64 bronze.

TD5S Unit

The United Type TD20S pumper has 19.7 A.P.I. nominal hp. rating, 97,500 in-lb. peak torque, double-reduction, overall gear ratio 26.2 to 1, herringbone continuous tooth gears, clamshell brake, high and intermediate shaft, and is equipped with Hyatt high-load roller bearings. Crankshaft bearings are S.A.E. 64 bronze. All exposed shafts are equipped with Chicago rawhide seals, all bolts are of high-tensile steel and have nut and lock nuts. Cranks are split hub alloy iron. The counterbalance is of the rotary type; 100-lb. insert weights can be easily added. The walking beam has an A.P.I. capacity rating of 15,750 lb. Polished-rod stroke is 24 in.-34 in., 44 in.-54 in. The wristpins taper and are equipped with Shaffer self-aligning roller bearings. The oil-bath equalizer and center bearings are of S.A.E. 64 bronze. Pitmans are fully equalized. The samson post, four post, and welded-in jigs are reinforced with gussets and braced for rigidity. All bolts have nut and lock nuts.

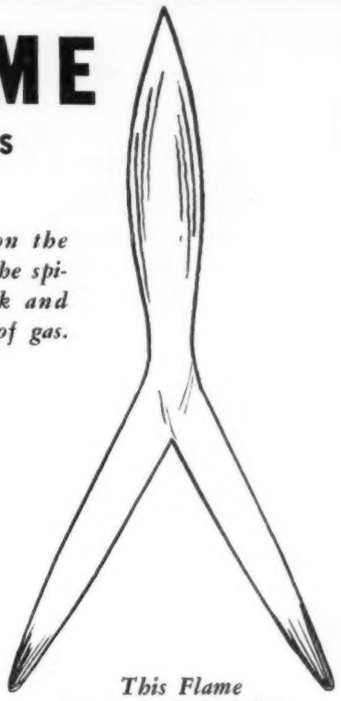
TD20S Unit

HEAT WITHOUT FLAME

When Burning Gases of Varying Heat Values

John Zink Bi-Mix Burners are so installed that all air entering the firebox passes through the radiating arm spiders, making an efficient steam generator. The fuel to these burners is often switched from natural gas, to residue, to propane without adjustment.

Impinging jets on the radiating arm of the spider insure quick and thorough mixing of gas.



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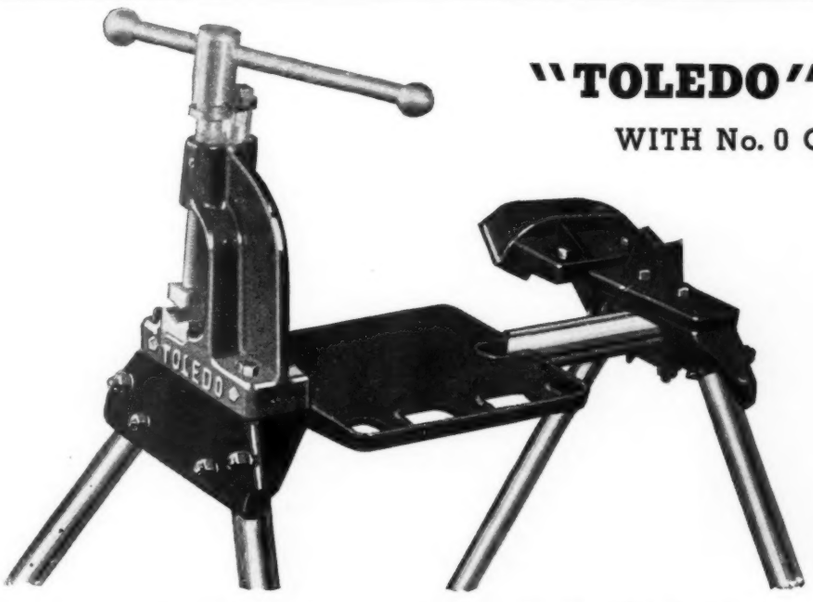

Tool tray accommodates oil can, pipe wrench, pipe cutter, stocks and dies.
Pipe bender handles pipe up to one inch without kinking.
Vise holds ⅛" to 2½" pipe.

"TOLEDO" HANDY STAND

WITH No. 0 OPEN-SIDE PIPE VISE

An exceedingly handy vise stand and vise assembly. Quickly and easily assembled or taken down on the job. No legs or connecting brace furnished. User makes up legs from 1" pipe and connecting brace from 1¼" pipe. Sold with or without tool tray or pipe bender. High grade malleable iron and heat treated steel. Ask your dealer for the low net prices.

THE TOLEDO PIPE THREADING MACHINE COMPANY

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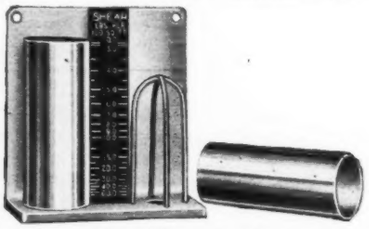
"TOLEDO"

YOU'LL DO BETTER WITH A "TOLEDO"

Baroid's Shearometer for Field-Testing Gel Strength of Drilling Mud

THE Shearometer has been introduced by the Baroid Sales Department and is an A.P.I.-approved instrument for the field determination of the shear or gel strength of drilling fluids.

The Baroid Shearometer set, as illustrated, consists of two 5-gram Shearometer tubes, a direct-reading scale, and a holder. Two Shearometer tubes are included so that two determinations



may be made without having to clean and dry each tube after every test.

The shear or gel strength is determined in terms of force per unit area. Consequently the scale is calibrated to read directly in lb. per 100 sq. ft. in a range from 3 lb. per 100 sq. ft. to 60 lb. per 100 sq. ft. with the 5-gram Shearometer. Readings down to 1.5 lb. per 100 sq. ft. are possible by using a 2.5-gram Shearometer that is also available. To use the scale with this type, it is necessary to divide the scale reading by two to obtain the correct gel strength reading.

To run a test with the Shearometer it is merely necessary to place the equipment very gently on a quiescent surface of the mud sample and allow it to sink vertically until it comes to rest. The depth of the penetration is then measured on the scale and the gel strength read directly therefrom in lb. per 100 sq. ft.

The Shearometer not only affords a simplified means of determining the gel strength of drilling mud but has the added advantage of being able to measure the mud's resistance to the settling of an object through the mud. This resistance is comparable to that offered by the mud in the system in opposing the settling of cuttings.

Further data on construction of the Shearometer and its proper use, as well as prices, can be obtained from Baroid Sales Department offices at Los Angeles, California, Houston, Texas, and Tulsa, Oklahoma.

End Shields for U. S. Motors

U. S. Electrical Motors are now available with unimount end shields. These end shields have a flat surface to facilitate the mounting of pumps and other directly driven equipment and for mounting magnetic brakes. They may be assembled on either end of the motor and can be used to mount a footless motor to a machine frame if desired.

The unimount end shields may be obtained in a number of standardized outside diameters, mounting machine fits, and bolt circles. They are also available unmachined, which allows the user to machine the mounting dimension to suit his particular unit.

Unimount end shields eliminate the necessity for an adapter, save mounting time, provide Uniclosed Drip-Proof protection for the motor, conserve space, and harmonize with both the motor and the application, the manufacturer states.

Further information is obtainable from U. S. Electrical Motors, Inc., Dept. 106, 80 34th Street, Brooklyn, New York.

For DIGGING LOW COST DITCH

"Anywhere — Anytime —"

Put "CLEVELANDS" "On the Line"

If it's results you're after, you'll get them with "Clevelands." "Clevelands" go through delivering maximum performance at surprisingly low costs. And there's a reason—correctness of design, alertness to field requirements, plus Quality of Construction.

Time-tested, time-proven, compact, fast, flexible, stream-lined for light weight, easy to move around the country, yet rugged and abundantly powered, "Clevelands" have the built-in qualities to enable you to get pipe line in the ground quickly, with least "times-out" and at lowest cost. "Clevelands" are sold on a guaranteed satisfaction basis. Get the details — write today.

THE CLEVELAND TRENCHER COMPANY

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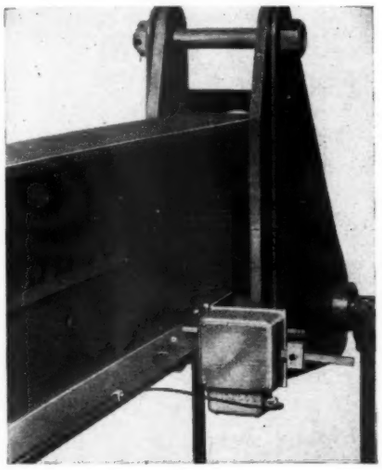
One important "Cleveland" idea that adds to the versatility of performance is illustrated at right — low cost transportation, at truck speed, via special trailer — "Clevelands" load or unload in 10 to 15 minutes.

"CLEVELANDS" *Save More* — Because they *Do More*

Ideco Sentinel Power Cut-out Switch

THE Ideco Sentinel Power Cut-out Switch, manufactured by International Derrick and Equipment Division, International-Stacey Corporation, Columbus, Ohio, is designed for use on wells where rod-string breaks are frequent. The manufacturer asserts that this equipment has been found to be a reliable means of protecting pumping equipment from the serious damage so frequently caused by the power continuing to drive the machine after a break occurs.



The working principle of the switch is simple. It consists of a pivoted arm that is held in the operating position by means of a permanent magnet. When the force on the arm exceeds the force of attraction in the magnet, the arm drops by gravity and a mercury switch grounds the magneto in an internal-combustion engine or de-energizes the magneto switch of an electric motor. The Sentinel Power Cut-out Switch is a non-reclosing switch. When the arm drops it is held in the disengaged position by gravity.

One of the most valuable features of the switch is the provision for adjusting its sensitivity. This adjustment is accomplished by moving a weight along the lever arm. A delicate adjustment is used for deep wells in which the reaction from a rod break is slight.

The Sentinel Power Cut-out Switch may be installed on any type of pumping rig without the necessity of special field fabrication. It is equipped with means for clamping to the flange of a steel beam or bolting to a wooden beam. The installation consists simply of attaching the switch to the walking beam and connecting the lead wire to the magneto or the magnetic switch.

The Ideco Sentinel Power Cut-out Switch is a safeguard against damage to all parts of the machine because it shuts-off the power immediately if the rods break or a part fails, the makers state.

Rotary Hose Features Built-in, Leak-proof Coupling

TWO TYPES of rotary hose for use in rotary drilling operations, distributed by The Continental Supply Company, Dallas, Texas, now feature the incorporation of a built-in, leak-proof coupling.

This hose and coupling, according to the announcement, is regarded as an outstanding development in the history of rotary hose manufacture. Available in both "Super Rough Rider" and "Rough Rider" brands, the hose features a coupling that is an integral part of the product.

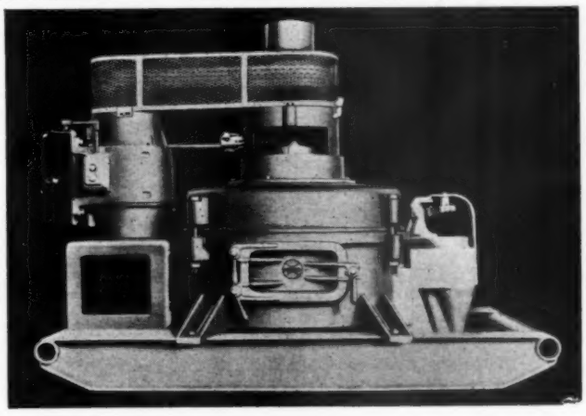
The built-in coupling eliminates the necessity of flanges, nozzles, bolts, nuts, clamps, and hydraulic nipples. Made of the toughest alloy steel obtainable, the coupling has been shown to be leak-proof in thorough field tests, it is stated.

Literature is available from The Continental Supply Company.

MAINTAIN MUD WEIGHT

WITHOUT TREMENDOUS LOSSES OF MUD-WEIGHTING MATERIALS

In maintaining desired mud-weight, it is no longer necessary to dispose of surplus weighted-mud which has picked up colloids, gas and water from the formation. With the new Merco Type A-24 Concentrator, the weighting material can be concentrated in the mud stream. A small flow (10 to 25 gallons per minute) of previously desanded, weighted-mud is fed into the Concentrator. Excess colloids, gas and water are desanded and the weighting material is concentrated up to a density of 120 lbs./cu. ft. The concentrates are then remerged with the circulating mud stream, continuously restoring the original mud-weight.



The Merco Type A-24 Concentrator differs from the Merco Type A-24 Desander in application and construction. The Merco Concentrator is specifically designed for concentrating mud-weighting materials while the Desander is designed for extracting sand and cuttings from the mud. The Concentrator is constructed for much higher speed, and has other refinements not embodied in the Desander.

MERCO *the* **MERCO** TYPE A-24 **CONCENTRATOR**

Write Today for Complete Details

MERCO CENTRIFUGAL CO., Division C-1, 343 Sansome St., San Francisco, California
Manufacturers of Merco Type A-24 Desander for Rotary Drilling Mud

MERCO CENTRIFUGAL CO.
Division C-1, 343 Sansome Street
San Francisco, California

Please send me full details on the New Merco Type A-24 Concentrator.

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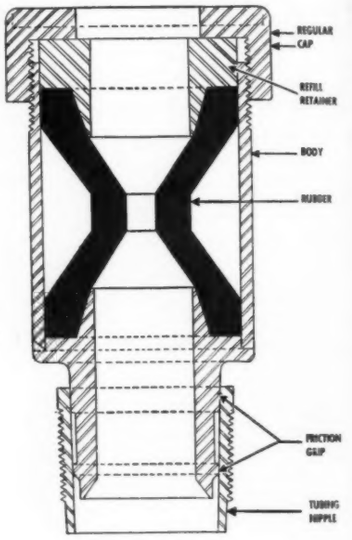
Sucker-Rod Wiper

AN inexpensive, effective sucker-rod wiper for low-pressure wells has been developed by Patterson-Ballagh Corporation. A replaceable spool of wear-resistant rubber is incorporated within a housing equipped with either a regular cap or a safety cap. Only the rubber comes in contact with the sucker rod. The rods are effectively wiped so that no appreciable oil remains on the rod or coupling, the manufacturer states. When the pump reaches the surface it is unnecessary to slow down because the friction grip of the body is released by the slight impact against the rubber cushions and the wiper follows the pump up into the derrick.

A safety cover is available, having a double latch to hold couplings in event they start to drop back into the well. The body is a friction grip into a standard 3-in. pipe, having full clearance for all size pumps. The same grade of rubber used in the manufacture of Patterson-Ballagh drill pipe and casing protectors is used in this sucker-rod wiper.

Full details may be obtained by addressing Patterson-Ballagh Corporation, 1912 East 65th Street, Los Angeles, California.



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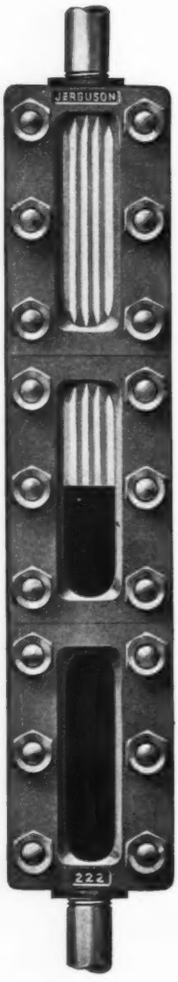

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Merla Announces Insert Pump Anchor

MERLA Tool Corporation, Dallas, Texas, announces a new Insert Pump Anchor. This anchor is simple to install. It is not necessary to pull tubing and no derrick is needed, a gin pole being sufficient to run the rods with the pump anchor attached.

By using this new Insert Pump Anchor the pump can be set at any depth and reset as desired without being removed from the tubing, it is stated. The economy of using the Merla Insert Pump Anchor lies in the fact that the device eliminates a tubing job, it is pointed out.

New mechanical construction features, as asserted by the manufacturer, follow:

The fluid area through the improved anchor is twice that of the previous model. The packing sleeve has been shortened and the new controlled expansion features added. New and heavier hook-wall assembly with improved friction springs make this anchor easier to set and reset. The slotted cone having knurling inside and on the tube, gives this new anchor the Merla patented hold-down feature while pumping. The pump adapter can be supplied to fit any standard insert pump.

Price list and engineering data are available from the Merla Tool Corporation, P. O. Box 2576, Dallas, Texas.